DOCUMENT RESUME

ED 300 605 CE 051 247

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|---|---|
| TITLE | Gas Metal Arc Welding. Welding Module 5. Instructor's Guide. |
| INSTITUTION | Missouri Univ., Columbia. Instructional Materials Lab. |
| PUB DATE | 88 |
| NOTE | 132p.; Printed on variously colored paper. For related modules, see CE 051 243-250. |
| AVAILABLE FROM | Instructional Materials Laboratory, 10 London Hall, University of Missouri, Columbia, MO 65211. |
| PUB TYPE | Guides - Classroom Use - Guides (For Teachers) (052) |
| EDRS PRICE | MF01/PC06 Plus Postage. |
| DESCRIPTORS | Behavioral Objectives; *Competency Based Education; *Equipment Utilization; Learning Activities; Learning Modules; Lesson Plans; *Metal Working; Secondary Education; *Trade and Industrial Education; *Welding |

ABSTRACT

This guide is intended to assist vocational educators in teaching an eight-unit module in gas metal arc welding. The module is part of a welding curriculum that has been designed to be totally integrated with Missouri's Vocational Instruction Management System. The following topics are covered in the module: safety and testing, gas metal arc welding machines, wire classification and problem solving, welding principles, carbon steel, techniques for welding on aluminum and on stainless steel, and flux-cored arc welding. The materials included in the module have been formatted for competency-based teaching and testing. All information sheets, transparency masters, job sheets, assignment sheets, and test items are keyed to specific competencies, and a cross-reference table has been included to aid in identifying the parts of the curriculum that relate to specific competencies. Unit tests to evaluate specific competencies have also been provided. (MN)

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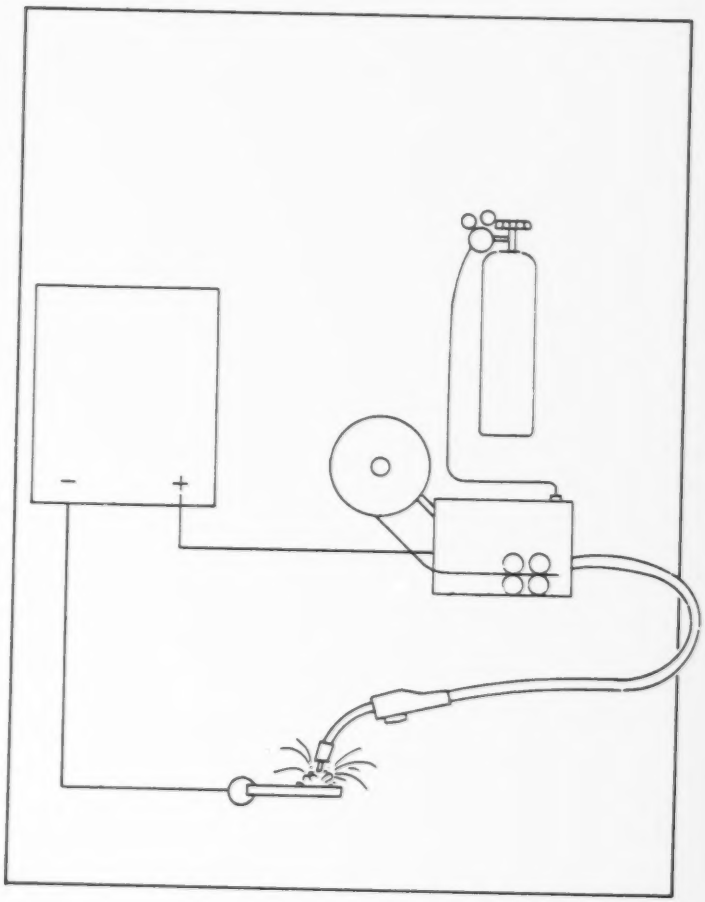
ED300605



# ELDING • Module 5

## Gas Metal Arc Welding (GMAW)

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## Module: GMAW

### Cross-Reference Table of Instructional Materials

| Competency | Instructional Objective | Transparency Master | Handout | Assignment Sheet | Job Sheet | Test Item | Notes |
|---|---|---|---|---|---|---|---|
| I1 | I 1.1-1.10 | | | I1.1, 1.2 | | I1-24 | |
| I2 | II 2.4 | | | | | II 28, 30 | |
| I3 | II 1.3, 1.4 | | II 1.1 | | II 1.2 | | |
| I4 | II 1.1, 1.2, 1.4, 2.1-2.3, 2.5 | II 1.1 | | | II 1.1 | II 1-27, 29, 31 | |
| I5 | III 1.1, 1.2 | III 1.1 | | | | III 1, 2, 6 | |
| I6 | III 1.3 | III 1.1 | | | | III 7, 8 | |
| I7 | III 1.4 | III 1.1 | | | | III 9 | |
| I8 | III 1.5 | | III 1.1 | | | III 10, 11 | |
| I9 | | | III 1.1 | | | III 3-5 | |
| I10-12 | IV 1.4, VIII 1.13 | | | | IV 1.1, VIII 1.1 | | |
| I13 | | | | | IV 1.1 | | |
| I14 | IV 2.1, VIII 1.13 | | | | IV 2.1, VIII 1.2 | IV 4, 5 | |
| I15 | VI 1.1 | | | | VI 1.1 | | |
| I16 | VII 1.1 | | | | VII 1.1 | | |
| I17 | IV 2.2, VIII 1.13 | | | | IV 2.2, VIII 1.2 | IV 17 | |
| I18 | VI 1.1 | | | | VI 1.1 | | |
| I19 | VII 1.1 | | | | VII 1.1 | | |
| I20 | IV 2.2 VIII 1.13 | | | | IV 2.2, VIII 1.2 | IV 7, 8 | |

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## Module: GMAW (cont.)

### Cross-Reference Table of Instructional Materials

| Competency | Instructional Objective | Transparency Master | Handout | Assignment Sheet | Job Sheet | Test Item | Notes |
|---|---|---|---|---|---|---|---|
| I21 | IV 2.2, VIII 1.13 | | | | IV 2.2, VIII 1.2 | | |
| I22 | IV 2.3 | | | | IV 2.3 | IV 9 | |
| I23 | VI 1.1 | | | | VI 1.2 | | |
| I24 | VII 1.2 | | | | VII 1.2 | | |
| I25-28 | V 1.1 | | | | V 1.1 | | |
| I29-31 | V 2.1 | | | | V 2.1 | | |
| I32 | III 2.1, 2.2 | | | | | III 13, 14 | |
| I33 | I 2.2, 2.3 | | | | I 2.1, 2.2 | | |

## MODULE: GAS METAL ARC WELDING

## UNIT I: SAFETY AND TESTING

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to discuss GMAW safety, handle welding and cooling cables properly and understand eye hazards associated with arc burn. The student should also be able to list safe clothing requirements, discuss environmental safety in the work place, solve problems concerning GMAW safety and test welded joints. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

## SPECIFIC OBJECTIVES

1.1 Match terms related to GMAW safety with definitions.

1.2 Select true statements concerning electrical safety for GMAW.

1.3 Select true statements concerning duty cycle safety.

1.4 Complete statements concerning important rules for handling cables and gas and coolant hoses.

1.5 Solve problems concerning GMAW safety.

1.6 Complete statements about types of welding hoods.

1.7 Complete a list of steps in selecting a safe lens shade for GMAW.

1.8 Select statements concerning protective clothing required in arc welding.

1.9 Complete statements concerning environmental safety requirements.

1.10 Differentiate between true and false statements concerning safety guidelines for working with electrode wire.

2.1 Identify parts of a fillet weld.

2.2 Bend test a fillet weld.*

2.3 Bend test a welded V groove joint.*

*Addresses competency on profile

## MODULE: GAS METAL ARC WELDING

## UNIT I: SAFETY AND TESTING

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: SAFETY

a. Information outline

b. Assignment sheet

AS 1.1: Occupational lung hazards
AS 1.2: Problems concerning GMAW safety

2. Lesson 2: WELDMENT TESTING PROCEDURES

a. Transparency

TM 2.1: Parts of a fillet weld

b. Job sheets

JS 2.1: Bend test a fillet weld
JS 2.2: Bend test a welded V groove joint

E. Unit test

F. Answers to unit test


## REFERENCES


A. Books

1. Horwitz, Henry. Welding Principles and Practices. Boston: Houghton Mifflin Company, 1979.

2. Sacks, J. Raymond. Welding Principles and Practices. Peoria, Ill.: Charles A. Bennett Co., Inc., 1976.

B. Curriculum guides

1. Fortney, Clarence, and Mike Gregory. Gas Metal Arc Welding and Flux-Cored Arc Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

C. Pamphlets

1. "What's Your I.Q. on Occupational Lung Hazards?" (#1202) St. Louis: American Lung Association, 1983.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches for teaching this unit

1. Test procedures presented in Lesson 2 will be used for job sheets throughout the Gas Metal Arc Welding module. Students should be referred to the test procedures each time they complete welds.

2. AS 1.1 can be used as a pre-test to check students' awareness of potential lung hazards.

3. Contact representatives from the American Lung Association or other organizations to give class safety presentations.

B. Suggested student activities

1. Teach students maintenance tasks, such as mounting reels and coils of wire on machines; changing wire rolls; and changing contact tips, diffusers, liners and insulators.

C. Suggested supplemental materials

1. Videotapes from The Media Center, State Fair Community College, Sedalia, Mo.

   a. Basics of MIG Welding (W-79-120). 1979.

   b. Fuel Gas Welding Safety (W-77-103). 1977.

   c. Inspection and Testing of Welds: Non-Destructive Tests (W-88-330). 1988.

   d. Inspection and Testing of Welds: Destructive Tests (W-88-331). 1988.

2. Microwire Welding (EW300). Troy, Ohio: Hobart Brothers Company.

## MODULE: GAS METAL ARC WELDING

## UNIT I: SAFETY AND TESTING

## LESSON 1: SAFETY WITH GMAW

I. Terms and definitions

A. Contaminants--impurities formed from chemical reactions between base metals, flux and electrodes. Usually present in fumes and vapors

B. Duty cycle--performance reference used to avoid overheating a welding machine

C. GMAW (gas metal arc welding)--an arc welding process where a weld is made by feeding a consumable wire electrode at a controlled rate into a weld joint while a continuous blanket of shielding gas is fed into the weld joint to shield the weld zone from contaminants

D. MIG (metal inert gas)--another abbreviation often used to mean GMAW

E. NEMA--National Electrical Manufacturer's Association

F. Oxygen displacement--a reduction of oxygen in the breathing zone around a welding activity caused by any arc or flame

G. Toxic hazards--poisonous gases, fumes and vapors produced by chemical reactions in certain welding processes

II. Electrical safety for GMAW welding

A. All electrical equipment should have an earth ground. This ground should not be confused with the work lead to workpiece ground that completes the welding circuit.

B. Keep electrical connections tight, clean and dry because poor connections can heat up, cause bad welds, produce dangerous arcs and sparking, and even melt.

C. Keep work area, equipment and clothing dry--even a slight amount of moisture can conduct enough electricity to cause a severe shock.

D. Never dip a gun in water to cool it.

E. When working with welding machines set for multiple operation, be very careful not to touch hot parts of the gun; open-circuit voltages from two machines are increased and can cause a severe shock.

F. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

G. Keep welding cables as close to the work area as possible. Do not connect cables to building framework because current can be directed through lifting chains and cables, weakening them.

H. When working in high places, carefully examine work area for electrical hazards. A shock under such conditions could cause a fall and severe injury.

III. Duty cycle safety

A. Duty cycle is a performance reference used to avoid overheating and perhaps ruining a welding machine.

B. Duty cycle is based on a 10-minute period and the length of time during that period that a machine can be safely operated.

(Example: A machine with a 20% duty cycle be used for two minutes at maximum amperage out of each 10-minute period.)

C. Since duty cycle is rated at the maximum output of a welding machine, the lower the percentage, the more attention is required to time spent actually welding.

D. Use the NEMA classification on the welding machine as a guideline to safe operation.

1. Class I is rated for output at duty cycles 60, 80 or 100%.

2. Class II is rated for output at duty cycles of 30, 40 or 50%.

3. Class III is rated to deliver output at a duty cycle of 20%.

IV. Important rules for handling cables and gas and coolant hoses

A. Never drag cables or hoses through dirt or oil. Never pull on a cable to force it over an obstruction.

B. Use only clean, dry rags to clean cables and hoses. Never use gasoline or an oily rag for the job.

C. When not in use, keep cables and hoses coiled free of kinks and properly stored.

D. Never drape a welding cable over any type of gas cylinder.

E. Never interchange gas and water hoses.

V. Hazards associated with arc rays

A. A welding arc produces ultraviolet and infrared radiation that can severely burn eyes unless unprotected with a proper shade of lens.

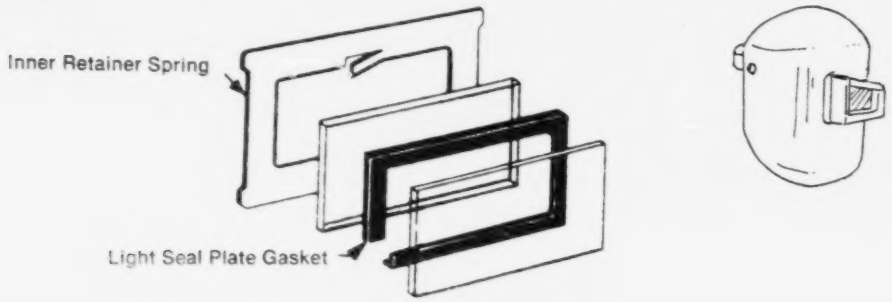
NOTE: A welding hood or helmet protects the head from flying sparks, but the shaded lens is also required for eye protection, as are safety glasses.

B. Welding arc radiation is strong enough to sunburn or blister bare skin if exposure is intense or for an extended periods. Arms, legs and torso should be covered with durable, flame-resistant clothing.

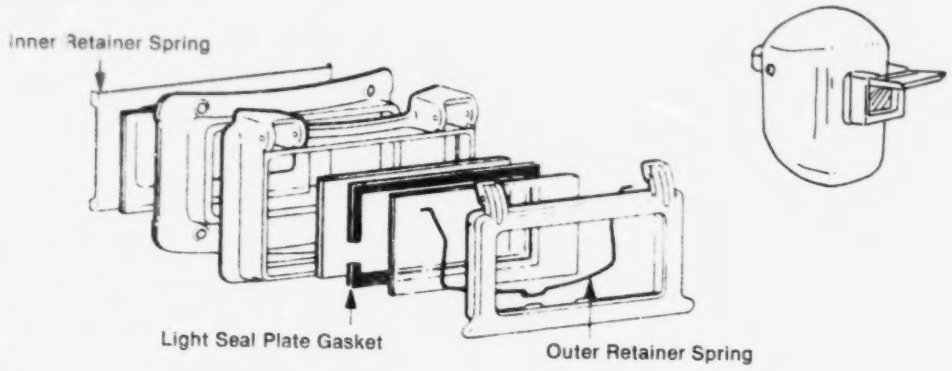
C. Work stations and work areas should be shielded to keep an arc flash from injuring nearby workers or visitors.

VI. Types of welding hoods

A. Stationary filter lens: This type of hood has a fixed lens housing with the shaded lens held in by a spring retainer which allows lens replacement as the welding requires.




B. Flip-front filter lens: This type of hood has a lens housing with a front side that can be flipped up, leaving a clear-glass lens that permits the hood to be worn while cleaning.




VII. Selecting a safe lens shade for GMAW

A. Determine electrode size and amperage range for the electrode.

NOTE: In oxy-acetylene welding and cutting, lens shade requirements are based on metal thickness, but in gas-shielded arc welding, lens shade requirements are based on electrode size, the amperage range of the electrode and the base metal properties.

B. Select lens shade according to the lens manufacturer's selection chart, but never select less than a #9 lens shade for GMAW.

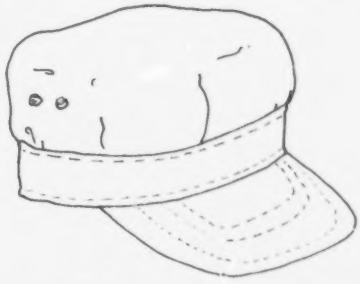
**CAUTION:** If you remove the hood after welding and see white spots or white blotches as after images, too much light is getting through the lens. Switch to a shade at least one number darker or check the seal on your lens.

| Base metal | Wire/ electrode size | Shade # |
|---|---|---|
| Nonferrous | 1/16-5/32 | 11 |
| Ferrous | 1/16-5/32 | 12 |

C. A general rule of thumb is that the larger the diameter of the electrode, the higher the number required for a lens shade.

VIII. Protective clothing required for welding

A. Welder's cap: Has a flexible bill that can be slipped around to cover either ear; keeps sparks or metal spatter out of the ear



B. Shirts and pants: Heavy, long-sleeve shirts with pockets that have flaps; cuffless pants that are not frayed at the bottom. Avoid clothing made of synthetic materials.

C. Leather jackets and aprons: Should be worn for additional protection, especially when welding out of position or in confined areas where flying sparks present an increased hazard

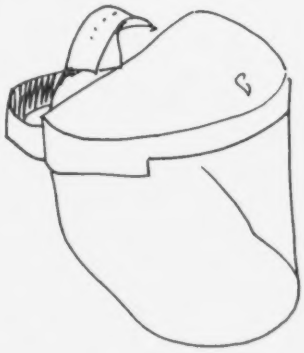
D. Boots: Should be made of heavy leather with tops that reach above the ankle to help prevent burns from sparks and spatter. Although steel-toed boots are not required, they are highly recommended.

E. Gloves: Heavy leather gloves with gauntlets are required for all welding and cutting activities.

F. Safety glasses: Should have non-metal frames, impact-resistant lenses with side shields to protect from flying objects. Wear at all times in the shop area.

NOTE: Safety glasses should meet industry and OSHA specifications.

G. Face shield: Should be a clear-plastic type to provide good visibility when grinding or sanding base metals for GMAW.



IX. Environmental safety requirements

A. Ventilation: Many welding activities produce toxic fumes and vapors that are hazardous to breathe. Every work station should be equipped with a ventilation or exhaust system capable of safely removing dangerous and irritating smoke and contaminants.

**CAUTION:** Always position your head to the side of rising fumes.

B. Respirators: In confined areas where the hazard of toxic fumes is increased, a welder should wear an air-supplied respirator or a self-contained breathing apparatus, instead of a filter-type mask, to compensate for oxygen displacement.

C. Noise: This is a frequently overlooked work place hazard. Ear plugs or muffler-type ear protectors should be worn when the work area subjects a welder to high noise levels, especially high noise levels that are continuous.

D. Lighting: Lighting in a work area should be bright enough to provide good, glare-free visibility since a poorly lit work area contributes to eye fatigue, irritation and poor work.

X. Safety guidelines for working with electrode wire

A. Always wear safety glasses when working with electrode wire because a loose end could spring up and severely injure an eye.

B. Use the correct spool or coil before loading and cutting tie wires.

C. Hold the free end of electrode wire firmly to avoid backlash during the reloading procedure. Failure to do this could ruin an entire spool or coil.

D. Position coils close to the reel before lifting. Lift with your legs, not your back--standard coils weigh 50-60 pounds.

E. Never look into a gun while you're feeding wire through it. Never point the gun at anyone else.

F. Never place your finger or hand over a contact tip to see if the wire is feeding properly.

# OCCUPATIONAL LUNG HAZARDS

**Write a T before the statements you believe to be true and an F before those which are false.**

___ 1. A ventilation system that exhausts dirty air reduces work place breathing hazards.

___ 2. Occupation-related lung diseases usually develop quickly.

___ 3. After you've been on the job a while, your lungs build up a tolerance to most hazards.

___ 4. Coarse dusts breathed at work are more dangerous than fine dusts because they scratch the bronchial tubes.

___ 5. Breathing bad air at work is less dangerous if your lungs are accustomed to cigarette smoke.

___ 6. Vacuuming or ventilating dusts at work is better protection than wearing a mask.

___ 7. Offices and institutions, as well as factories, can have dirty air.

___ 8. Dangerous substances in the air at work can be dependably detected by smell or sight.

___ 9. Breathing hazards in the work place can cause asthma.

___ 10. Unlike industrial workers, farmers have nothing to fear from the air they breathe at work.

## SOLVE PROBLEMS CONCERNING GMAW SAFETY

**Read the following statements carefully. Write a brief statement that recommends a specific solution if there is a safety violation presented.**

1. A fellow student is attempting to repair a malfunctioning gun while the welding machine is still on. Is there a problem? ___

   Solution: _____

   _____

2. You are working at maximum capacity with a welding machine that has a 39% duty cycle and realize that you've been welding for almost five minutes without stopping. Is there a problem? ____

   Solution: _____

   _____

3. A co-worker is using an oily rag to clean a welding cable. Is there a problem? _____

   Solution: _____

   _____

4. It is hot and you are perspiring. You decide it is safe to roll up your sleeves to be a little more comfortable while welding. You are certain no sparks will hit you, so you feel safe. Is there a problem? _____

   Solution: _____

   _____

5. You notice a co-worker reloading a coil of electrode wire without wearing safety glasses. Is there a problem? ____

   Solution: _____

   _____

INSTRUCTOR'S NOTE: Completion of this assignment sheet to specified score is the student's partial evaluation for competency I1: Demonstrate safety procedures.

## ANSWERS TO ASSIGNMENT SHEET 1.1

INSTRUCTOR'S NOTE: Students who score below 80% are especially susceptible to lung hazards.

1. T. Good ventilation can remove hazards after they appear, but it's better to prevent such hazards.

2. F. Many occupational lung diseases take years to develop. This is a major problem in controlling them.

3. F. 200,000 Americans are partially disabled by diseases caused by respiratory irritants found in the work place.

4. F. Very fine dusts are more dangerous because they can go deeper into the lungs.

5. F. Cigarette smoking increases the danger of developing work-related lung diseases.

6. T. Vacuuming or ventilating dusts removes them. A mask is difficult to wear all the time.

7. T. Indoor air pollution--dusts, gases and smoke--can occur in offices and institutions.

8. F. Often workers don't realize a dangerous substance is in the air (carbon monoxide, for example).

9. T. There is even a disease called occupational asthma.

10. F. Sometimes farmers develop lung diseases from such things as moldy hay, animal hair and bird feathers.

## ANSWERS TO ASSIGNMENT SHEET 1.2

INSTRUCTOR'S NOTE: Student answers should approximate those given.

1. Yes. All electrical power sources should be disconnected before working on any electrical equipment.

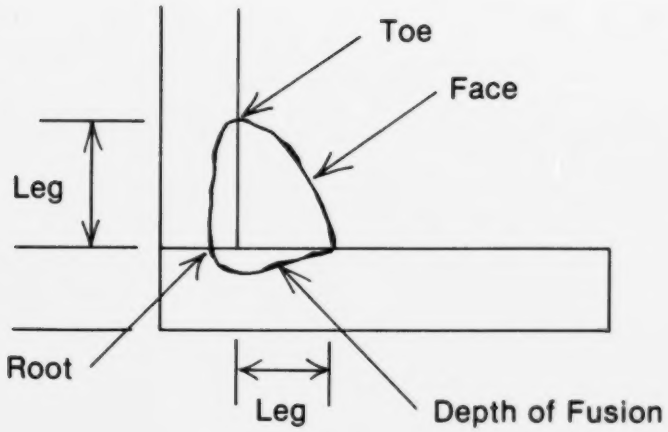
2. Yes. You've exceeded the safe limits of the duty cycle and should stop welding and check equipment or wait a safe time before continuing.

3. Yes. Only clean, dry rags should be used to clean cables and hoses.

4. Yes. Even though sparks may not injure you, the radiation from the arc is strong enough to sunburn or sometimes blister bare skin.

5. Yes. Always wear safety glasses when working with electrode wire because a loose end could spring up and injure an eye.

## PARTS OF A FILLET WELD

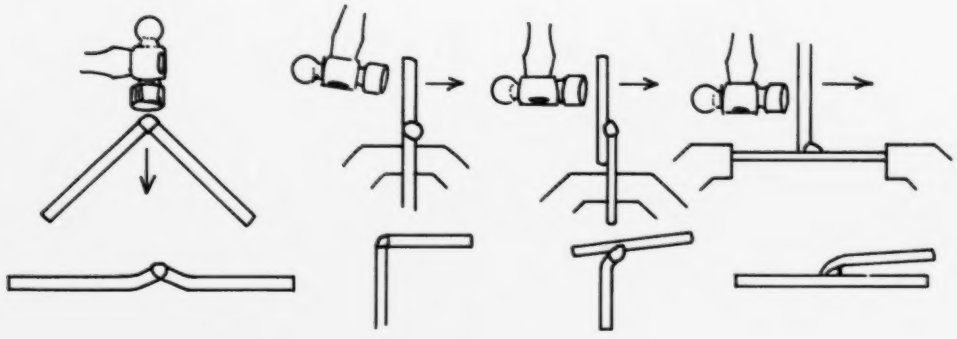


# BEND TEST A FILLET WELD

Equipment:

Personal safety clothing and equipment
Bench vise
Fitter's hammer
Safety glasses
Pliers
Welded lap joint as selected by instructor or from a previous job sheet

| Procedure | Evaluation 3 2 1 N |
|---|---|
| 1. See illustration below for proper vise positioning. | — — — — |



| | |
|---|---|
| 2. Strike the plate that is not secured in a direction that will cause it to break away from the plate that is secured in the vise. | — — — — |
| 3. Inspect break to make sure the line of the break is centered down the joint. Also inspect for good penetration, fusion or any defects. | — — — — |
| 4. Ask instructor to check your work. | — — — — |
| 5. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. | — — — — |
| Average of above evaluations* | — — — — |

*This average is the student's partial evaluation for competencies A15 and I33.

# BEND TEST A WELDED V GROOVE JOINT

Equipment:

Bend test machine
Oxy-acetylene cutting unit
Portable hand grinder
File
Pliers
Groove-weld test plate, minimum 3/8" thick

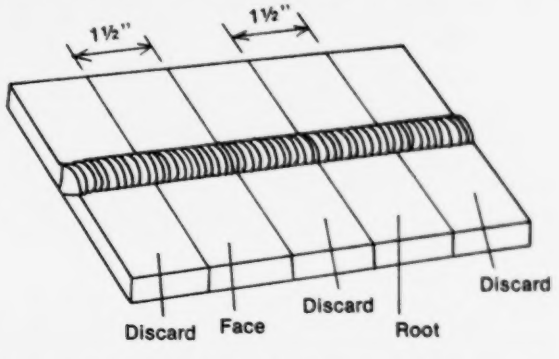
Personal safety clothing and equipment
Soapstone
Straightedge
Cutting goggles
Sparklighter

Procedure:

Evaluation 3 2 1 N

1. Check work area to make sure it is free of flammable materials and is well ventilated. Note the location of the nearest fire extinguisher. — — — —

2. Place test plate out on the work table in front of you; use straight edge and soapstone to mark off bend specimens for a face bend and a root bend. Mark specimens F and R for identification. — — — —




3. Set up oxy-acetylene equipment. Light and adjust cutting flame; cut specimens perpendicular to the weld as marked. — — — —

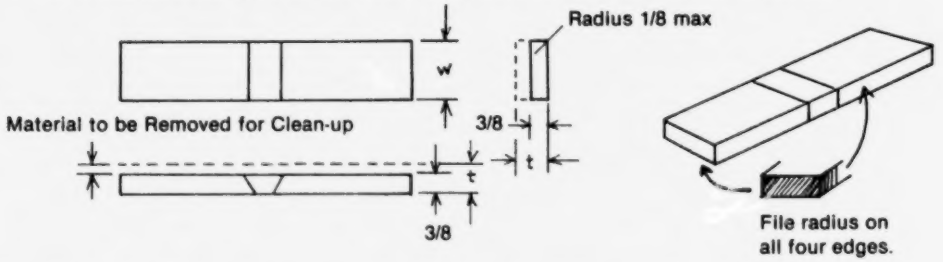
4. Turn off torch and shut down cutting unit. — — — —

5. Permit specimens to air cool--do not quench them in water or they will be unsuitable for testing. — — — —

6. Secure cooled specimens--one at a time--in vice and use a portable grinder to grind to the following specifications. Grind welds lengthwise <u>with</u> weld direction--not across weld, which will cause cracks to show up along the grinding marks when tested. — — — —

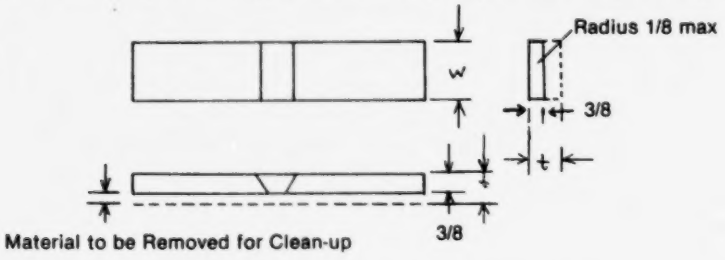
a. Face bend specimen for a plunger-type tester should be a minimum of 6" long, 1 1/2" wide and ground so that both the root and face of the weld are flush with the surface of the specimen. _____

NOTE: For a wraparound-type tester, a longer specimen will probably be required.



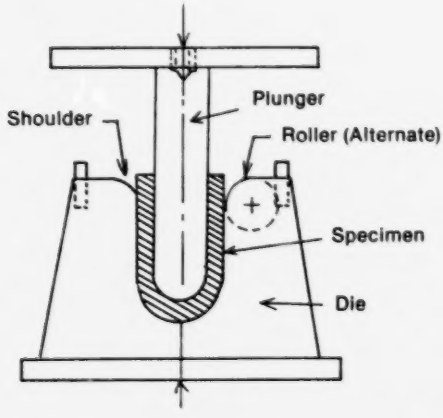

b. Root bend specimen for a plunger-type tester should be a minimum of 6" long, 1 1/2" wide and ground so that both the root and face of the weld are flush with the surface of the specimen.

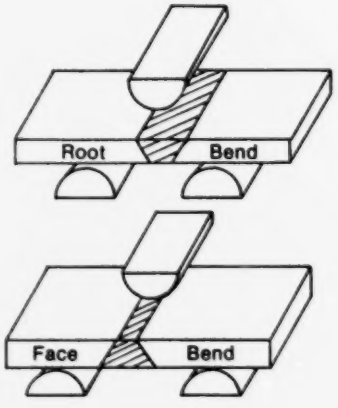
NOTE: For a wraparound-type tester, a longer specimen will probably be required.




7. Grind or file the corners of both specimens for a 1/16" radius. _____

8. Take specimens to plunger-type tester and make bends according to the following procedure. _____



a. Place face bend specimen on the die member of the jig with the weld face pointing into the die so that the plunger is on the root side of the weld.

b. Start the plunger forcing the specimen between the plunger and the die until it is formed into a U shape.

**CAUTION:** Always wear safety glasses when conducting bend tests.

c. Release plunger pressure to free specimen.

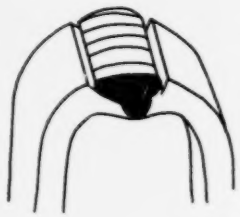
9. Repeat the testing procedure for the root bend, but reverse the root and face of the weld as you place it on the die. — — — —

10. Inspect test specimens. — — — —

a. Examine convex surface of both specimens for cracks or other open defects.

b. Check root bend to determine if weld has complete penetration through the joint.

c. Check face bend to determine if there is complete fusion of the beveled edges with the weld.



11. Ask instructor to check your bend test. — — — —

12. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competency A15: Perform a weld test (destructive/nondestructive).

## MODULE: GAS METAL ARC WELDING

## UNIT I: SAFETY AND TESTING

## UNIT TEST

**Match the terms on the right with appropriate definitions.**

| | | | |
|---|---|---|---|
| ____ 1. | A reduction of oxygen in the zone around a welding activity caused by any arc or flame | a. | Class I |
| ____ 2. | Poisonous gases, fumes and vapors produced by chemical displacement reactions in certain welding processes | b. | Class II |
| ____ 3. | Impurities formed from chemical reactions between base metals, flux and electrodes, usually present in fumes and vapors | c. | Class III |
| ____ 4. | National Electrical Manufacturer's Association | d. | Contaminants |
| ____ 5. | Performance reference used to avoid overheating of a welding machine | e. | Duty cycle |
| ____ 6. | NEMA classification for safe operation of a welding machine rated for output at duty cycles of 60, 80 or 100% | ab. | Filter-type mask |
| ____ 7. | Equipment necessary for safe breathing where toxic fumes are a hazard | ac. | NEMA |
| ____ 8. | NEMA classification for safe operation of a welding machine rated for output at a duty cycle of 20% | ad. | Oxygen displacement |
| ____ 9. | NEMA classification for safe operation of a welding machine rated for output at duty cycles of 30, 40 or 50% | ae. | Self-contained breathing apparatus |
| | | bc. | Toxic hazards |

**Choose the letter of the option which best answers the question or completes the statement.**

____ 10. For safety reasons, all electrical equipment should have ____ .

a. An earth ground
b. A work lead to workpiece ground
c. Ground connected to machine case
d. None of the above

____ 11. Which of the following is <u>not</u> a proper electrical safety guideline?

a. Keep electrical connections tight, clean and dry.
b. Keep work area, equipment and clothing dry.
c. Dip a gun in water to cool it only in emergencies.
d. When working with welding machines set up for multiple operation, be very careful not to touch hot parts of the gun.

___ 12. Which of the following is false?

a. Since duty cycle is rated at the maximum output of a welding machine, more attention to time spent welding is required with lower-rated machines.
b. Keep welding cables as close to the work area as possible, and do not connect cables to building framework.
c. When working in high places, carefully examine work area for electrical hazards.
d. Duty cycle is a performance reference used to avoid choosing the wrong welding cable.
e. Disconnect and lock out all electric power sources before doing any work on electrical equipment.

___ 13. Which is an approved method of handling cables and hoses?

a. A cable can be pulled over an obstruction.
b. Use gas or an oil rag to clean cables and hoses.
c. When not in use, cables and hoses can be coiled with some kinks in them.
d. Never drag cables or hoses through dirt or oil.

___ 14. Never drape a welding cable over any _____ ; never strike an arc on a ____.

a. Sharp piece of metal, non-metallic surface
b. Part of the body, gas cylinder
c. Gas cylinder, gas cylinder
d. Gas cylinder, non-metallic surface

___ 15. Gas and water hoses _____ .

a. Can be interchanged if cleaned first
b. Should never be interchanged
c. Are the same thing
d. Have left-hand threads

___ 16. Which is not an arc ray hazard?

a. Ultraviolet light
b. Eye burn
c. Arc flash
d. Sunburn or blistering

___ 17. The _____ type of welding hood has a _____ lens housing with the shaded lens held in by a spring retainer.

a. Stationary filter lens, flexible
b. Flip-front lens, flexible
c. Flip-front lens, fixed
d. Stationary filter lens, fixed

___ 18. When choosing an electrode, what are two things to determine first?

a. Duty cycle and electrode amperage range
b. Duty cycle and electrode size
c. Electrode size and electrode amperage range
d. None of the above

___ 19. Select lens shade according to the lens manufacturer's selection chart, but never select less than a _____ lens shade for GMAW.

a. #5
b. #7
c. #9
d. #11

___ 20. A general rule of thumb is that the _____ the diameter of the electrode, the _____ the number required for a lens shade.

a. Smaller, higher
b. Larger, higher
c. Larger, smaller
d. None of the above

___ 21. Which of the following does not describe proper GMAW protective clothing?

a. Boots should be made of heavy leather. Steel-toed boots are not recommended because they are too heavy and cause fatigue.
b. A welder's cap has a flexible bill that can be slipped around to cover either ear and keep sparks or metal spatter out of the ear opening.
c. Leather jackets and aprons should be worn for additional protection.
d. Heavy leather gloves with gauntlets are required for all welding and cutting activities.

___ 22. Which of the following does not describe proper GMAW protective clothing?

a. Wear heavy, long-sleeved shirts with pockets that have flaps and cuffless pants that are not frayed at the bottom.
b. Safety glasses should have nonmetal frames, impact resistant lenses with side shields to protect from flying objects. They should be worn only when preparing metal for welding.
c. Face shields should be a clear-plastic type to provide good visibility when grinding or sanding base metals.
d. Heavy leather gloves with gauntlets are required for all welding and cutting activities.

___ 23. Which type of work place hazard is most frequently overlooked?

a. Ventilation
b. Lighting
c. Noise
d. None of the above

___ 24. When working with electrode wire, which of the following is false?

a. Always wear safety glasses when working with electrode wire because a loose end could spring up and severely injure an eye.
b. Check feeding by placing your finger or hand over the contact tip.
c. Make sure you have the correct spool or coil before loading and cutting tie wires.
d. Never look into a gun while you're feeding wire through it. Never point the gun at anyone else.

Identify the following parts of a fillet weld.

___ 25.
___ 26.
___ 27.
___ 28.
___ 29.
___ 30.

a. Depth of fusion
b. Face
c. Leg
d. Root
e. Toe

NOTE: Completion of this unit test to a specified score is the student's final evaluation for competency I1. Demonstrate safety procedures.

## ANSWERS TO UNIT TEST

1. ad (I1)
2. bc (I1)
3. d (I1)
4. ac (I1)
5. e (I1)
6. a (I1)
7. ae (I1)
8. c (I1)
9. b (I1)
10. a (I1)
11. c (I1)
12. d (I1)
13. d (I1)
14. c (I1)
15. b (I1)
16. a (I1)
17. d (I1)
18. c (I1)
19. c (I1)
20. b (I1)
21. a (I1)
22. b (I1)
23. c (I1)
24. b (I1)
25. d
26. c
27. e
28. b
29. a
30. c

## MODULE: GAS METAL ARC WELDING

## UNIT II: GMAW MACHINES

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to identify GMAW machine controls and discuss their functions, set up a GMAW machine, and identify characteristics of short-circuit metal transfer and spray-arc metal transfer. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

## SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student will be able to:

1.1 Match machine controls with functions.

1.2 Match electrical controls and functions.

1.3 Answer questions concerning wire feeder controls, functions, adjustments and preventative maintenance.

1.4 Demonstrate the ability to:

a. Set up GMAW machine.*

b. Set up GMAW flow meter.*

2.1 Match terms and definitions related to GMAW equipment, applications and techniques.

2.2 Identify characteristics of short-circuit metal transfer.

2.3 Identify characteristics of spray-arc metal transfer.

2.4 Identify functions and characteristics of various GMAW shielding gases.

2.5 Define electrode stickout and its function in GMAW.

*Addresses competency on profile.

## MODULE: GAS METAL ARC WELDING

## UNIT II: GMAW MACHINES

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the Instructor

D. Lesson plans

1. Lesson 1: EQUIPMENT SET-UP AND FUNCTIONS

   a. Information outline

   b. Transparency master

      TM 1.1: The GMAW system

   c. Handout

      HO 1.1: Types of gun tip components

   d. Job sheets

      JS 1.1: Set up GMAW machine
      JS 1.2: Set up GMAW flow meter

2. Lesson 2: TYPES OF TRANSFER MODES

   a. Information outline

E. Unit test

F. Answers to unit test


## REFERENCES

A. Books


1. Giachino, Joseph and William Weeks. Welding Skills and Practices. Chicago: American Technical Publishers, Inc., 1976.

2. Horwitz, Henry. Welding Principles and Practices. Boston: Houghton Mifflin Company, 1979.

3. Sacks, J. Raymond. Welding Principles and Practices. Peoria, Ill.: Charles A. Bennett Co., Inc., 1976.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Walk students through problem areas such as cleaning wire rolls, removing wire from tip and reconditioning tip for use, removing a bird's nest in rollers, replacing liners, changing different sizes and kinds of wire, or setting amps and volts by sound and bead appearance.

2. Invite a welding supplier representative to discuss the variety of machines and applications.

## MODULE: GAS METAL ARC WELDING

## UNIT II: GMAW MACHINES

## LESSON 1: EQUIPMENT SET-UP AND FUNCTIONS

I. GMAW machine controls and functions (TM 1.1, HO 1.1)

A. Coolant solenoid--an on-off switch or valve that activates coolant flow in water-cooled GMAW systems

B. ESO (electrode stickout)--the distance from the contact tip of the gun to the electrode's end (sometimes called electrical stickout)

C. Flow meter regulator--used to reduce high-pressure cylinder gas to low-pressure gas so its flow rate can be controlled to the welding gun as measured in CFH (cubic feet per hour)

D. Gun--trigger-operated, on-off device through which wire, shielding gas and coolant are controlled at the weld zone

E. Gun and cable assembly--cable transports power to trigger-operated gun through which the wire, shielding gas and coolant pass

F. Power supply--a rectifier-type DC welding machine with controls for current and voltage used in the basic GMAW processes

G. Wire feeder--a roller device used to vary and control the speed at which wire is fed to the welding arc in relation to amperage and wire feed speed

II. GMAW electrical controls and functions

A. On-off switch--starts or stops electrical power to a GMAW machine

B. Voltage range selector--controls wide-range voltage selection such as 12-28 volts for low range and 20-35 volts for high range

C. Fine voltage control--used to fine-tune the voltage selection within the wide-range setting

D. Power supply voltmeter--used to calibrate and check voltage adjustments

E. Power supply ammeter--used to calibrate and check amperage adjustments

F. Slope--increases or decreases the rate of resistance change in a welding machine for pinch control (minimizes spatter)

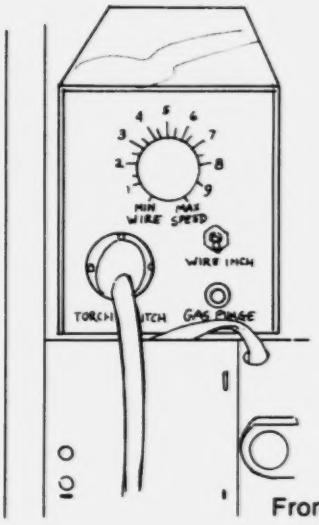
G. Polarity switch--changes polarity from DCRP to DCSP so meters for amps and volts can be properly read

H. Contactor--completes circuit through wire feed and function as an on-off device for wire feed

I. Inductance--controls arc-on time in short-circuit welding to control puddle fluidity and produce a flat, smooth weld bead

III. Wire feeders

A. Controls and functions



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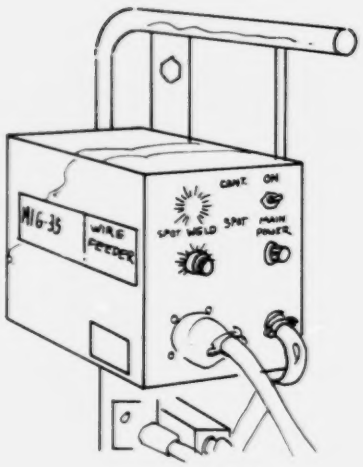


Back

1. On-off switch--controls power input into wire feed mechanism

2. Amp/ipm--functions as a dual control to regulate wire feed rate in inches per minute in relation to amperage

3. Contactor dropout--increases or decreases burn back on ESO

4. Spot weld function--an on-off device that routes current through a timer that provides a specific time for each trigger activation regardless of how long or briefly the trigger is held

5. Purge--a device to permit purging of a shielding gas through the gun without having wire feed at the same time

6. Wire-inch switch--advances wire for set-up purposes; does not activate other components

7. Wire feed volt and ammeters--used to calibrate and adjust volts and amps in the wire feed mechanism

8. Remote unit--a control that makes voltage adjustment possible in situations where welding activity and machine adjustments are not within reach

   NOTE: Remote units are self-contained and usually have long extension cords. Some guns have remote adjustment capabilities built in.

9. Reverse control--a handy device that permits the rewinding and reuse of excess wire spooled off during loading

B. Roll adjustment requirements

1. When the tension on wire feeder rolls is too tight, the rolls may flatten or shave the wire.

2. A flattened wire will usually "bird nest" at the feed roll and will not feed through the cable.

3. A shaved wire creates small flakes of wire around the feed rolls and could create an electrical hazard or make the wire "bird nest."

4. Wire should not be too tight or too loose.

5. Most wire feeders have rollers for different sizes of wire. The proper roller size should be checked.

C. Preventive maintenance requirements

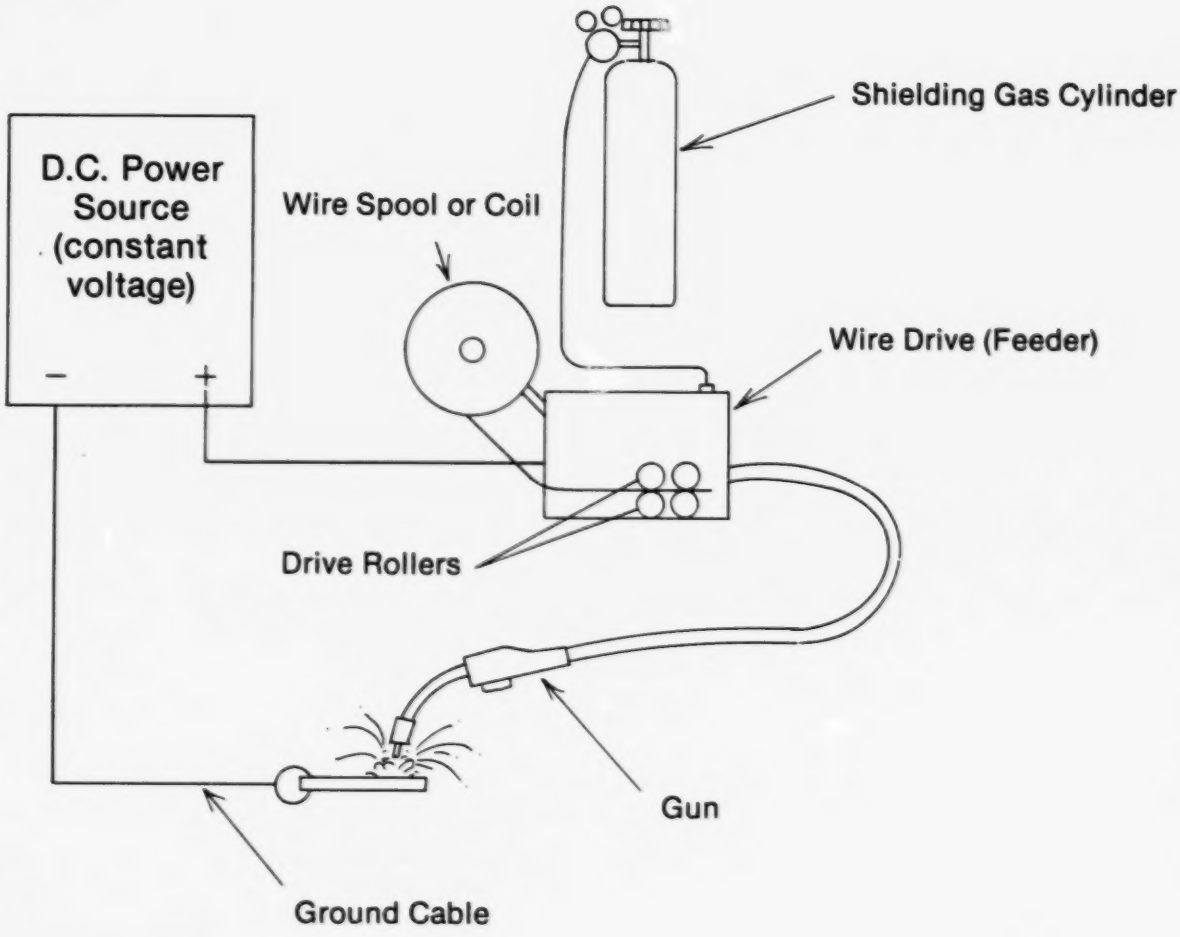
1. Feed rolls should be checked and cleaned daily.

2. All electrical connections into and out of the feeder should be checked daily and tightened as required.

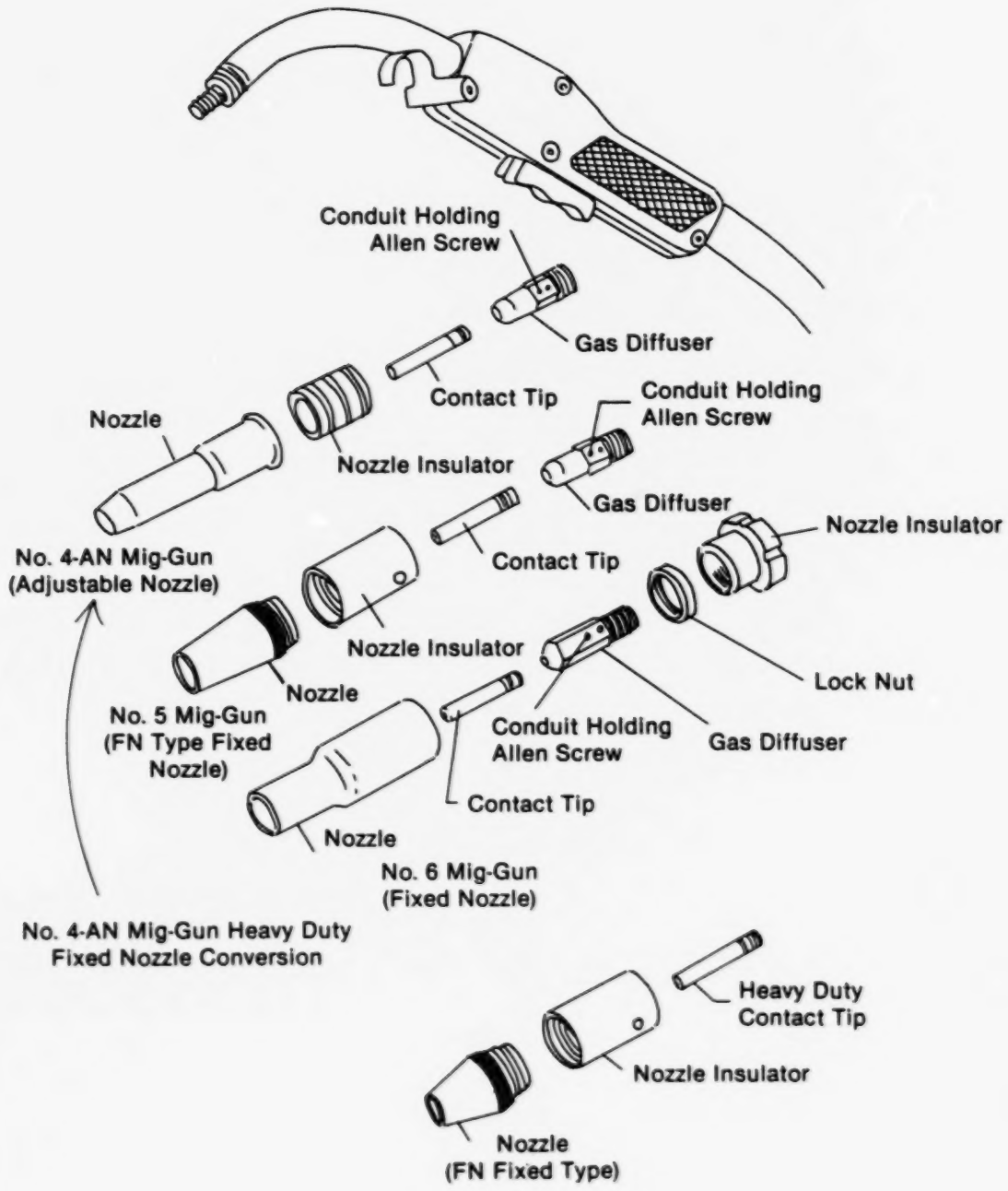
3. The drag brake needs to be checked before each use to make sure it feeds off smoothly with no free wheeling.

4. All gas hoses and connections should be inspected for leaks before each operation.

# THE GMAW SYSTEM



## TYPES OF GUN TIP COMPONENTS



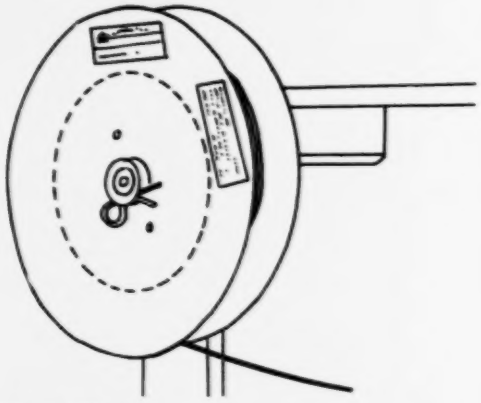

GMAW 41

# SET UP GMAW MACHINE

Equipment:

GMAW machine and accessories
Personal safety clothing and equipment
GMAW wire, spool or coil
Screwdriver
Adjustable wrench
Wire-cutting pliers

| Procedure | Evaluation 3 2 1 N |
|---|---|
| 1. Shut off input power to power supply and wire feeder. Remove nozzle and tip from MIG gun. | — — — — |
| 2. Cut tip of wire off at ESO, if replacing wire. Use pliers to slide contact tip out over wire--be careful not to remove the gas diffuser. | — — — — |
| 3. Release spring tension off the feed roll. Pull remaining wire through cable and gun if replacing wire and dispose of it. | — — — — |
| 4. Remove the retaining collar that holds the spool in place by loosening the thumb screw or removing the cotter pin that secures it. | — — — — |



| | |
|---|---|
| 5. Remove the empty spool from the spindle. | — — — — |
| 6. Locate the end of the wire on the new spool and position the new spool so that the wire will feed from the bottom of the spool into the wire feeder. | — — — — |

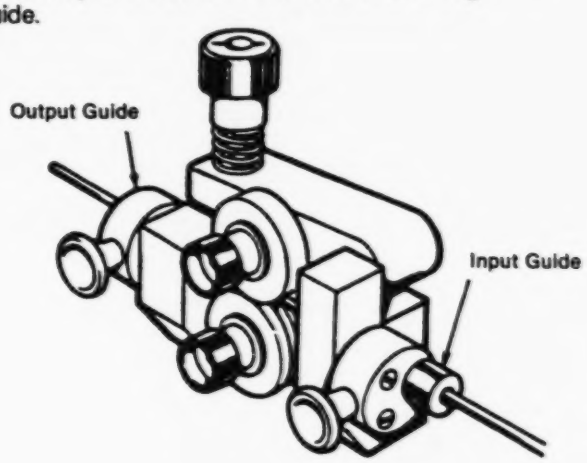
**CAUTION:** Do not remove the free end of the wire from the retaining hole where it is secured or wire will spill all over.

| | |
|---|---|
| 7. Place the new spool onto the spindle and make sure the drag brake pin slips into the proper hole. | — — — — |

8. Place the retaining collar back on the spindle. Force it tightly against the reel and tighten the thumb screw or replace the cotter pin that secures it. — — — —

9. Locate the end of the wire on the spool. Free it from the retaining hole and clip the end of the wire. — — — —

10. Use a file to smooth the sharp end of the wire. Guide the clean, free end of the wire through the insulated input guide; use both hands to push and pull the wire across the top of the bottom feed roller and through the insulated output guide. — — — —




11. Continue pushing and pulling the wire until it moves into and through the wire feed power assembly 2-3". — — — —

**CAUTION:** Do not force the wire into the wire feed assembly. Just work it back and forth until it fits smoothly.

12. Bring top feed roll down so that the wire lies in the groove between both the rollers. — — — —

13. Use screwdriver or thumb screw to tighten the pressure adjusting screw to provide operating pressure between the bottom and top rollers. — — — —

**CAUTION:** Do not overtighten the adjusting screw and cause the wire to flatten out.

14. Turn power supply and wire feed power on. Position gun so that the cable conduit between the wire feeder and gun is straight. — — — —

**CAUTION:** Use the wire-inch for the following adjustment because it will help prevent the gas diffuser's shorting out and wasting expensive shielding gas. If machine does not have a wire-inch, be especially attentive to the procedure.

15. Turn on the wire-inch and feed the wire through the cable conduit to the gun while testing tension on the feed roller with the following procedure. — — — —

    a. Pinch the wire just ahead of the insulated input guide.

    b. If a slight pinching pressure will stop the wire from feeding through, tension is probably right.

    c. If a slight pinching pressure will not stop the wire from feeding through, the tension is probably too tight.

16. Turn off power supply and wire feed supply. Replace the contact tip with pliers. Replace nozzle over contact tip.

17. Ask instructor to check your work. — — — —

    NOTE: The procedure for replacing a coil-type wire reel is essentially the same as that for a spool-type reel, except that the coil-type reel has a spring-loaded device to secure and release it so that the reel separates into two halves when a replacement coil is installed.

18. Adjust machine for specified welding activity. — — — —

19. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's partial evaluation for competency I4: Identify, select and set up equipment and explain functions.

# SET UP GMAW FLOW METER

Equipment:

Argon or helium cylinder ($CO_2$ C25 Cylinder)
Flow meter regulator
Adjustable wrench or 1 1/8" open-end wrench
Safety glasses

Procedure:

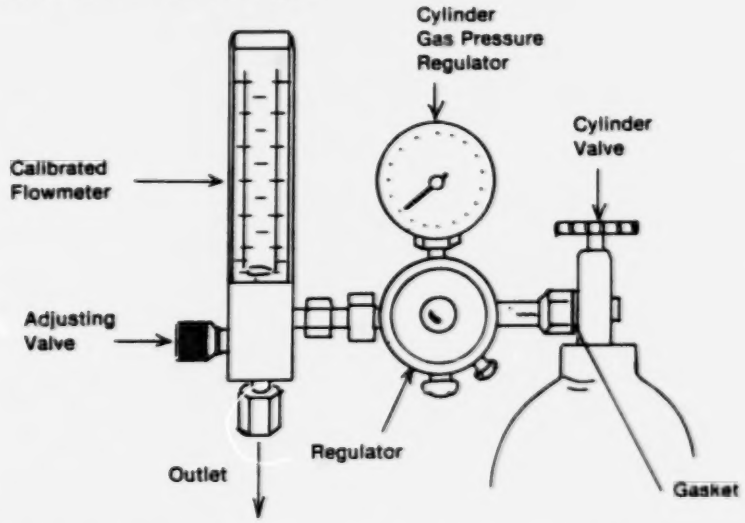
Evaluation
3 2 1 N

1. Check to see that gas cylinder is safely secured in an upright position. Remove cylinder cap. — — — —

2. Crack cylinder valve slightly to clear cylinder valve fitting. Check gasket and attach flow meter regulator to the cylinder valve. — — — —

3. Tighten regulator fitting nut with wrench, but do not overtighten. — — — —

4. Check to make sure that flow meter adjusting valve is shut off. If it isn't, turn it clockwise until it is tight. — — — —




5. Open gas cylinder valve all the way so that it will back seat against the top of the valve. — — — —

6. Set up and turn on GMAW machine. (Check with instructor.) — — — —

7. Turn flow meter adjusting screw counter-clockwise until the ball starts to rise in the flow meter. If ball is not rising, check to see if wire feed is turned on. — — — —

8. Move the adjusting screw clockwise or counter-clockwise to make adjustment to CFH desired. — — — —

   NOTE: The very top of the ball is the reference point for measuring CFH.

9. Ask instructor to check your work. — — — —

10. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competency I3: Adjust current, voltage, wire feed rate and gas flow.

## MODULE: GAS METAL ARC WELDING

## UNIT II: GMAW MACHINES

## LESSON 2: TYPES OF TRANSFER MODES

I. Terms and definitions

A. GMAW (gas metal arc welding)--an arc welding process where a weld is made by feeding a consumable wire electrode at a controlled rate into a weld joint while a continuous blanket of shielding gas is fed into the weld joint to shield the weld zone from contaminants

B. Inductance--the rate of rise of current as opposed to the final amount of current available. Used in short-circuit transfer to increase or decrease the number of short-circuit metal transfers per second

C. MIG (metal inert gas)--another abbreviation frequently used to mean GMAW

D. Short-circuit transfer--a GMAW application where small-diameter wire and low currents are used to weld thin metal mostly in the flat and horizontal positions

E. Slope--the slant of the volts versus amp curve, or the volts change per 100 amps

F. Slope control--a control on a power supply that regulates the amount of pinch force available on welding wire and controls spatter in short-circuit transfer

II. Characteristics of short-circuit metal transfer

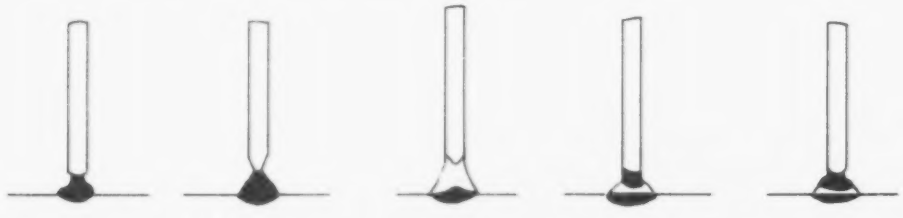
A. Metal does not transfer across the arc but melts off when the electrode wire makes contact with the base metal.

B. Amperage is controlled by wire feed speed.

C. Operating voltages range from 15-22 volts, depending on wire size and shielding gas.

D. The process is a relatively low-amperage, low-voltage technique that frequently uses a moderate slope adjustment to avoid excessive spatter.

E. Small diameter wires are used with this process.



1. Electrode short circuited
2. Current increased
3. Arc reignited
4. End of electrode heating
5. Electrode about to short circuit

III. Characteristics of spray-arc metal transfer

A. Metal transfer is made as a stream of tiny droplets moves across the arc from the electrode to the weld.

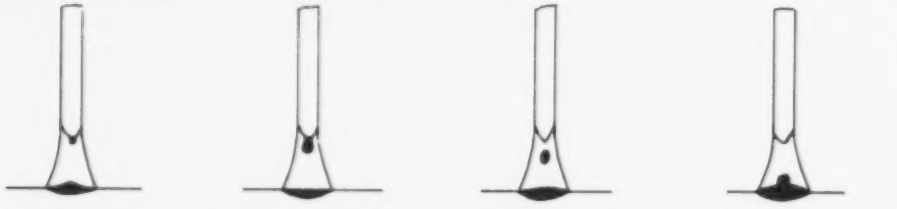
B. The process uses relatively high voltages and current; typical operating voltages range from 26-35 volts.

C. The spray-arc process has a characteristic sizzling or buzzing sound that usually indicates proper adjustment of all elements involved.

D. This process is used frequently with large diameter wires or thick metals.

E. Specific gases are required.

F. The spray-arc process provides the fastest deposition of weld metal on aluminum and excellent deposition rates on thick metals.



1. Droplet forming
2. Droplet being pinched off
3. Droplet in free flight
4. Droplet deposited

IV. Basic GMAW shielding gases and electrode wire selection

A. Shielding gases

1. Argon, $CO_2$ and oxygen are the three basic GMAW shielding gases. These gases are frequently used in combination to accomplish specific GMAW applications.

2. Argon is the most frequently used shielding gas because it produces a clean, narrow bead with deep penetration on nonferrous metals in both spray-arc and short-circuit transfer.

3. $CO_2$ is far less expensive than other shielding gases, but it can cause an unstable arc and produce spatter if not used carefully. $CO_2$ requires electrode wires with deoxidizing agents.

4. Oxygen is used in varying combinations with argon for both spray-arc and short-circuit transfer on mild and stainless steel.

NOTE: Helium mixed with argon is used for some aluminum applications, but helium does not produce as stable an arc as argon.

B. Rules of thumb for GMAW electrode wire selection

1. Solid electrode filler wires used for short-circuit transfer are usually small-diameter wires of .023", .030", .035" or .045".

2. Solid electrode filler wires used for spray-arc transfer are larger diameter wires of .045", 1/16", .68", 5/64", 3/32", 7/64", 1/8" or 5/32".

3. Electrode wire composition should match the base metal composition on which it will be used.

4. Since the objective of GMAW is to accomplish a high deposition rate at the lowest cost in materials and time, use the largest electrode size that can be used.

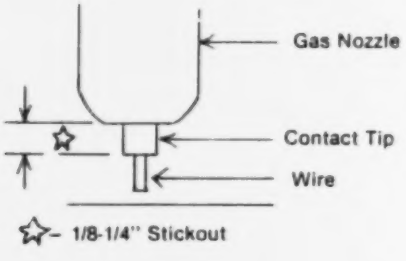
V. Electrode stickout (ESO) and its function in GMAW

A. ESO gives an operator control of slight but critical adjustments in amperage and voltage needed to correct spatter, penetration and bend width.

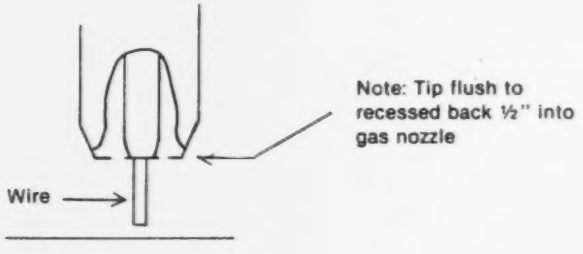
B. Too much ESO decreases amperage and slightly increases voltage. It results in more arc, which produces spatter and poor penetration.

C. Too little ESO increases amperage and slightly decreases voltage. It results in less arc, which gives no spatter and good penetration, but produces a narrow bead with overall poor fusion.

D. A normal ESO for short-circuit transfer is 1/4" to 3/8".




E. A normal ESO for spray-arc transfer is 3/4" to 1".



## MODULE: GAS METAL ARC WELDING

## UNIT II: GMAW MACHINES

## UNIT TEST

**Match wire feeder controls with functions.**

___ 1. Controls power input into wire feed mechanism

___ 2. Functions as a dual control to regulate wire feed rate in inches per minute in relation and ammeters to amperage

___ 3. Increases or decreases burn back on ESO

___ 4. An on-off device routing current through a timer that provides a specific time for each trigger activation

___ 5. A device to permit purging of a shielding gas through the gun without having wire feed at the same time

___ 6. Used to advance wire for set-up purposes; does not activate other components

___ 7. Used to calibrate and adjust volts and amps in the wire feed mechanism

___ 8. A control that makes voltage adjustment possible in situations where welding activity and machine adjustments are not within reach

___ 9. A handy device that permits excess wire to be rewound and reused

___ 10. Rectifier-type DC welding machine with controls for current and voltage used in the basic GMAW processes

___ 11. Used to reduce high-pressure cylinder gas to low-pressure gas so its flow rate can be controlled to the welding gun as measured in CFH (cubic feet per hour)

___ 12. Trigger-operated, on-off device through which wire, shielding gas and coolant are controlled at the weld zone

___ 13. Used to calibrate and check voltage adjustments

___ 14. Increases or decreases the rate of resistance change in a welding machine for pinch control (minimizes spatter)

___ 15. Used to calibrate and check amperage adjustments

a. Amp/ipm

b. Contactor dropout

c. Flow-meter regulator

d. Gun

e. On-off switch

ab. Power supply

ac. Power supply ammeter

ad. Power supply voltmeter

ae. Purge

bc. Remote unit

bd. Reverse control

be. Slope

cd. Spot weld function

ce. Wire feed volt and ammeters

de. Wire-inch switch

**Match the terms on the right with definitions on the left.**

___ 16. Arc welding process where a weld is made by feeding a consumable wire electrode at a controlled rate into a weld joint while a continuous blanket of shielding gas is also fed into the weld joint

___ 17. Abbreviation frequently used to mean GMAW

___ 18. Distance from the contact tip of the gun to the end of the electrode

___ 19. Slant of the volts versus amp curve; volts change per 100 amps

___ 20. Power supply control that regulates the amount of pinch force available on welding wire and controls spatter in short-circuit transfer

___ 21. GMAW application where small-diameter wire and low currents are used to weld thin metal mostly in the flat and horizontal positions

___ 22. GMAW application where high currents, high voltages and larger diameter wires are used to weld thick metal mostly in the flat and horizontal positions

___ 23. Rate of current rise as opposed to the final amount of current available; used in short-circuit transfer to increase or decrease the number of transfers

a. ESO
b. GMAW
c. Inductance
d. MIG
e. Short-circuit transfer
ab. Slope
ac. Slope control
ad. Spray-arc transfer

**Choose the letter of the most correct answer.**

___ 24. Spray-arc metal transfer is made as _____ moves across the arc from the electrode to the weld.

a. An alternating flow of molten metal
b. A stream of tiny droplets
c. Electric current
d. The shielding gas

___ 25. The spray-arc metal transfer process uses relatively _____ voltages and current. Typical operating voltages range from _____.

a. High, 40-55
b. Low, 15-22
c. Low, 10-15
d. High, 26-35

___ 26. The spray-arc process has a characteristic _____ sound that usually indicates proper adjustment of all elements involved.

a. Sizzling or buzzing
b. High-pitched
c. Low hum
d. Silent

___ 27. Spray-arc metal transfer is used frequently with _____-diameter wires on _____ metals.

a. Large, thick
b. Large, thin
c. Small, thin
d. Small, thick

___ 28. Which shielding gas gives the best penetration for spray-arc welding on aluminum?

a. Oxygen
b. Argon-oxygen mix
c. Argon
d. Argon-nitrogen mix

___ 29. One advantage of spray-arc metal transfer is that it provides the fastest deposition of weld metal on _____ .

a. Mild steel
b. Aluminum
c. Cast iron
d. Light-gauge metal

___ 30. Which shielding gas is far less expensive than others but can cause an unstable arc and spatter if not used carefully?

a. Argon
b. Oxygen
c. $CO_2$
d. Oxygen-argon

___ 31. Which is true of electrode stickout in GMAW?

a. Its function is to give an operator control of slight but critical adjustments in amperage and voltage needed to correct spatter, penetration and bend width.
b. Too much ESO decreases amperage and slightly increases voltage. It results in more arc, which produces spatter and poor penetration.
c. A normal ESO for short-circuit transfer is 1/4" to 3/8".
d. All of the above

NOTE: Completion of this test to a specified score is the student's final evaluation for competencies I2 and I4.

## ANSWERS TO UNIT TEST

| | | |
|---|---|---|
| 1. | e | (I4) |
| 2. | a | (I4) |
| 3. | b | (I4) |
| 4. | cd | (I4) |
| 5. | ae | (I4) |
| 6. | de | (I4) |
| 7. | ce | (I4) |
| 8. | bc | (I4) |
| 9. | bd | (I4) |
| 10. | ab | (I4) |
| 11. | c | (I4) |
| 12. | d | (I4) |
| 13. | ad | (I4) |
| 14. | be | (I4) |
| 15. | ac | (I4) |
| 16. | b | (I4) |
| 17. | d | (I4) |
| 18. | a | (I4) |
| 19. | ab | (I4) |
| 20. | ac | (I4) |
| 21. | e | (I4) |
| 22. | ad | (I4) |
| 23. | c | (I4) |
| 24. | b | (I4) |
| 25. | d | (I4) |
| 26. | a | (I4) |
| 27. | a | (I4) |
| 28. | c | (I2) |
| 29. | b | (I4) |
| 30. | c | (I2) |
| 31. | d | (I4) |

## MODULE: GAS METAL ARC WELDING

## UNIT III: WIRE CLASSIFICATION AND PROBLEM SOLVING

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to discuss AWS classifications for electrode or solid and cored wires for carbon steels; identify GMAW welding problems; know the causes and how to solve the problems. This knowledge will be evidenced by completion of the unit test to specified score.

## SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student will be able to:

1.1 Differentiate between proper and improper methods of storing electrode wire.

1.2 Solve problems concerning AWS classifications for electrode wires when welding carbon steels.*

1.3 Identify and select solid wire electrode for aluminum.*

1.4 Identify and select solid wire electrode for stainless steel.*

1.5 Identify types of cored wire electrodes for carbon steel and stainless steel.*

2.1 List characteristics of a good weld.

2.2 List common welding mistakes.

*Addresses competency on profile

## MODULE: GAS METAL ARC WELDING

## UNIT III: WIRE CLASSIFICATION AND PROBLEM SOLVING

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: AWS CLASSIFICATION FOR SOLID AND CORED WIRES

   a. Information outline

   b. Transparency master

      TM 1.1: Electrode wire classifications

   c. Handout

      HO 1.1: Typical flux-cored electrode operating variables

2. Lesson 2: GMAW WELDING PROBLEMS, CAUSES AND CURES

   a. Information outline

E. Unit test

F. Answers to unit test


## REFERENCES


A. Books

1. Carbon Steel Filler Metals for Gas Shielded Arc Welding (AWS code A5.20). Miami: American Welding Society, 1979.

B. Curriculum guides

1. Fortney, Clarence, and Mike Gregory. Gas Metal Arc Welding and Flux-Cored Arc Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Use a previously welded piece to point out good and bad points. (The instructor should be involved in welding the sample joints.)

2. Be sure students get booth practice as well as shop projects so that every student is accountable for work performed.

B. Suggested supplemental materials

1. Use industry charts (such as Hobart) to help illustrate electrode wire classifications.

## MODULE: GAS METAL ARC WELDING

## UNIT III: WIRE CLASSIFICATION AND PROBLEM SOLVING

## LESSON 1: AWS CLASSIFICATION FOR SOLID AND CORED WIRES

I. Special considerations for storing electrode wire spools and coils

A. Spools and coils of electrode wires should not be opened or unsealed until they are needed for immediate use.

B. Electrode wire should be stored in a dry place.

C. Spools or coils should be used as soon after opening as possible. Remaining wire should be covered or resealed prior to storage.

II. AWS classification for solid and cored electrode wires for carbon steels (TM 1.1)

A. AWS classifications for electrode wires use letter and number designations to identify type of electrode and basic composition.

B. As in other classifications, the letter E indicates electrode. When followed by the letter R, it indicates that the filler metal may be used as an electrode or welding rod.

C. Interior numbers indicate minimum tensile strength in multiples of 1,000 psi.

D. The letter S indicates a bare solid electrode or rod.

E. The letter T indicates a flux-cored tubed electrode.

F. Final letter-number classifications indicate special chemical compositions of the electrode wire.

III. AWS classification for aluminum electrode wires

A. AWS classification for electrode wires use letter and number designations to identify type of electrode and basic composition.

B. As in other classifications, the letter E indicates electrode.

C. The following numbers are a match for base metal according to American Iron and Steel Institute (AISI) grades.

1. E-4043 indicates this wire is to be used on 4043 grades of aluminum.

2. E-5356 indicates this wire is to be used on 5356 grades of aluminum.

IV. AWS classification for stainless steel electrode wire

A. AWS classification for electrode wires use letter and number designation to identify type of electrode and basic composition.

B. As in other classifications, the letter E indicates electrode.

C. The following numbers are a match for base metal according to AISI grades.

1. E-308 indicates this wire is to be used on 308 grades of stainless steel.

2. E-316 indicates this wire is to be used on 316 grades of stainless steel.

V. Classifications for flux-cored arc welding (FCAW) electrode wires (HO 1.1)

A. As with other AWS electrode classifications, the introductory E means electrode.

B. The second two digits indicate the tensile strength and welding position.

C. The T indicates the tubular construction of the flux-cored wire.

D. Final numbers or number-letter combinations indicate any special chemical composition of the wire.

E. The T and following number are also used to indicate whether or not the electrode is to be used self-shielded.

1. Self-shielded: all T-3, T-4, T-6, T-7, T-8 and T10 electrodes

2. Dual-shielded: all T-1, T-2 and T-5 electrodes

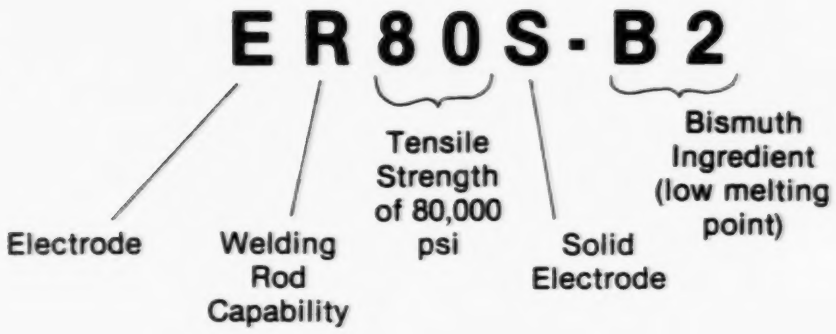
(Example: The T-4 in the E70T-4 designation indicates a self-shielded electrode.)

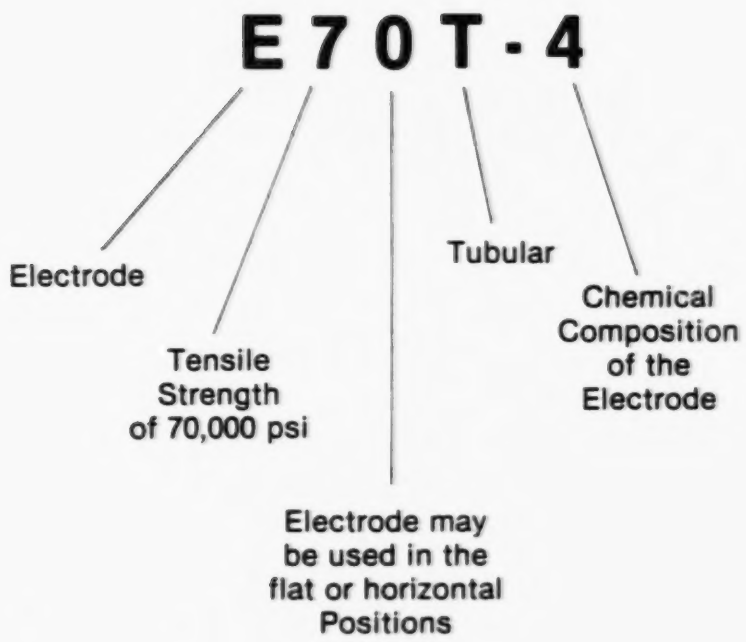
F. The T-3, T-4 and T-6 electrodes are designed for DCRP operations with fast wire-feed speeds and high amperage for high-deposition welding.

G. Other T-series electrodes are designed for DCSP for slower wire-feed speeds and lower amperages, but still provide fast travel and good penetration for special applications.

H. Other classifications include T-G, which covers multi-pass electrodes not covered under specific classifications, and T-GS, which covers single-pass electrodes of the same category.

## ELECTRODE WIRE CLASSIFICATIONS


E R 8 0 S - B 2
Electrode
Welding Rod Capability
Tensile Strength of 80,000 psi
Solid Electrode
Bismuth Ingredient (low melting point)


E 7 0 T - 4
Electrode
Tensile Strength of 70,000 psi
Electrode may be used in the flat or horizontal Positions
Tubular
Chemical Composition of the Electrode

# TYPICAL FLUX-CORED ELECTRODE OPERATING VARIABLES

| AWS class | Size | Polarity | ESO | Settings Normal arc voltage (volts) | Settings Wire feed speed (in/min.) | Approx. current (amps) | Deposition rate (lbs./hr.) |
|---|---|---|---|---|---|---|---|
| E71T-GS | .068" | DC(-) | 1/2" | 21 | 185 max. | 360 | 8.9 |
| | | | | 19 | 125 | 270 | 6.2 |
| | | | | 17 | 80 opt. | 185 | 4.0 |
| | | | | 15 | 60 | 140 | 3.0 |
| E71T-7 | .068" | DC(-) | 1" | 23 | 210 max. | 300 | 8.7 |
| | | | | 21.5 | 155 | 250 | 6.2 |
| | | | | 20.5 | 110 opt. | 200 | 4.2 |
| | | | | 19 | 70 | 150 | 2.4 |
| | | | | 18 | 55 | 100 | 1.7 |
| E71T-7 | 5/64" | DC(-) | 1" | 24 | 230 max. | 400 | 13.2 |
| | | | | 23 | 185 | 350 | 10.5 |
| | | | | 22 | 145 opt. | 300 | 8.0 |
| | | | | 21 | 110 | 250 | 5.8 |
| | | | | 20 | 75 | 200 | 3.7 |
| | | | | 19 | 55 | 150 | 2.4 |
| E71T-8 | 3/32" | DC(-) | | 22 | 120 max. | 350 | 8.6 |
| | | | | 21 | 110 | 330 | 7.8 |
| | | | | 20 | 95 opt. | 300 | 6.7 |
| | | | | 16 | 50 | 190 | 3.6 |

## MODULE: GAS METAL ARC WELDING

## UNIT III: WIRE CLASSIFICATION AND PROBLEM SOLVING

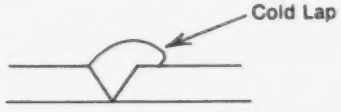
## LESSON 2: GMAW WELDING PROBLEMS, CAUSES AND CURES

I. Characteristics of a good weld

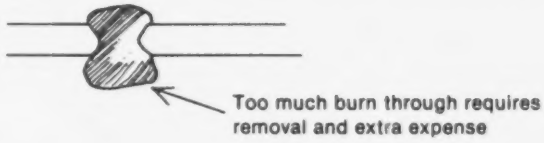
- A. Even ripple on bead
- B. Slight crown (convex) at root
- C. Well fused throughout joint
- D. Smooth starts and stops
- E. Correct leg length on fillet welds
- F. Straight, correctly sized bead

II. Common welding mistakes

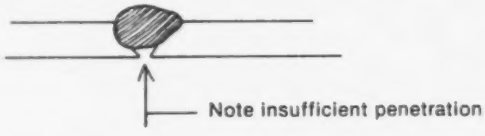
A. Cold lapping (incomplete fusion): excessive build-up of filler material with no penetration on excess




B. Excessive penetration: same as burn through (excessive build-up on root side of joint)




C. Insufficient penetration: not penetrating or burning through joint



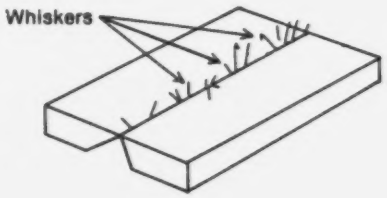

D. Burn-through: see excessive penetration

E. Surface porosity: holes on surface of weld caused by:

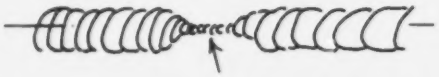
1. Shielding gas problem
2. Contaminate in welding area
3. Poor joint design

F. Poor appearance

G. Whiskers: wire electrodes allowed to go through joint without making an arc, which causes wire pieces to cling to root side




H. Bad tie-in: After stopping and restarting weld, good tie-ins must be made to ensure strength and soundness of welds.



NOTE: Bad tie-in as viewed from root side. Welder allowed filler metal to flow ahead of arc for a second or two, instead of keeping the wire on the puddle's leading edge.

I. Suck-back (internal concavity)

1. Bad joint fit-up
2. Improper voltage/amperage
3. Foreign material on root side
4. Position of welding

J. Improper ESO

K. Improper angle

L. Improper gas flow

M. Improper use of anti-spatter

N. Dirty nozzle

O. Failure to remove glass slag

III. Important points to remember in GMAW

A. Keep contact tip and nozzle clean and tight at all times. Use anti-spatter gel as welding conditions require.

B. Keep all cables free of kinks and pinches.

C. Although GMAW is one of the easiest welding processes, electrical settings must be finely tuned for the process to work.

D. Select the largest size wire that can be used for a given application so deposition rate will be increased.

E. Change only one variable at a time when adjusting current, volts, amperage or any electrical adjustment.

F. Keep arc in leading edge of puddle.

## MODULE: GAS METAL ARC WELDING

## UNIT III: WIRE CLASSIFICATION AND PROBLEM SOLVING

## UNIT TEST

**For the first five questions, choose the option which best answers the question concerning this example: ER70S-5.**

___ 1. What does the E stand for?

a. Electrode
b. Excellent
c. Extra strength
d. None of the above

___ 2. What does the R indicate?

a. Rolled
b. Rubellium
c. Regular
d. Rod

___ 3. What does the S stand for?

a. Steel wire
b. Stainless wire
c. Solid wire
d. Small wire

___ 4. What does the 70 designate?

a. 700 lbs. tensile strength
b. 7,000 lbs. tensile strength
c. 70,000 lbs. tensile strength
d. 700,000 lbs. tensile strength
e. None of the above

___ 5. What does the last number on the above system stand for?

a. Possible position use
b. Electrode chemical composition
c. Ultimate yield strength
d. Coating type

___ 6. In the E70T-4 classification, what two things do the T and the 4 mean?

a. Electrode is tubular and self-shielding.
b. Electrode is tubular and contains titanium flux.
c. Electrode is tubular and requires additional shielding.
d. None of the above

___ 7. Which wire electrode would be best used to weld 6160 aluminum?

a. E-4043
b. E-6061
c. E-316
d. None of the above

___ 8. Which wire electrode would be best for welding 4043 aluminum?

a. E-4043
b. E-6061
c. E-316
d. None of the above

___ 9. If welding 316 stainless steel, which electrode would be the best choice?

a. E-4043
b. E-6061
c. E-316
d. None of the above

___ 10. Which of the following flux-cored electrode wire endings indicate the wire is self-shielded?

a. T-1
b. T-2
c. T-5
d. T-6

___ 11. Which of the following flux-cored electrode wire endings indicate the wire is dual shielded?

a. T-3
b. T-4
c. T-5
d. T-6

___ 12. Which is <u>not</u> an appropriate consideration for storing wire spools or coils?

a. Open packages whenever convenient and place in leather holder.
b. Store in a dry place.
c. Use as soon as possible after opening.
d. Cover or reseal remaining wire prior to storage.

___ 13. List two characteristics of a good weld.

a.
b.

___ 14. List five common welding mistakes.

a.
b.
c.
d.
e.

NOTE: Completion of this test to specified score is the student's final evaluation for competencies I5 through I9 and I32.

## ANSWERS TO UNIT TEST

1. a (I5)
2. d (I5)
3. c (I9)
4. c (I9)
5. b (I9)
6. a (I5)
7. b (I6)
8. a (I6)
9. c (I7)
10. d (I8)
11. c (I8)
12. a

13. Any two of the following: (I32)
    Even ripple on bead
    Slight crown at root
    Well fused throughout joint
    Smooth starts and stops
    Correct leg length on fillet welds
    Straight, correctly sized bead

14. Any five of the following: (I32)
    Cold lapping
    Excessive penetration
    Insufficient penetration
    Burn-through
    Surface porosity
    Poor appearance
    Whiskers
    Bad tie-in
    Suck-back
    Improper ESO
    Improper angle
    Improper gas flow
    Improper use of anti-spatter
    Dirty nozzle
    Failure to remove glass slag

## MODULE: GAS METAL ARC WELDING

## UNIT IV: WELDING PRINCIPLES

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to build a pad of beads in all positions using gas metal arc welding. The student should also be able to make fillet welds to specification in various positions and make square groove butt joint in the flat position on carbon steel. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

## SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student will be able to:

1.1 Identify basic GMAW techniques.

1.2 Identify and practice techniques for properly ending a weld.

1.3 Apply positioning techniques and torch angles to various GMAW situations.

1.4 Build pads of beads.*

2.1 Make fillet weld in flat position.*

2.2 Make fillet welds in horizontal, vertical and overhead positions.*

2.3 Weld square groove butt joint on carbon steel in flat position.*

*Addresses competency on profile

## MODULE: GAS METAL ARC WELDING

## UNIT IV: WELDING PRINCIPLES

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: BUILDING PADS OF BEADS

   a. Information outline

   b. Job sheet

      JS 1.1: Build pads of beads

2. Lesson 2: GMAW FILLET WELDS

   a. Job sheets

      JS 2.1: Make fillet weld in flat position
      JS 2.2: Make fillet welds in horizontal, vertical and overhead positions
      JS 2.3: Weld square groove butt joint on carbon steel in flat position

E. Unit test

F. Answers to unit test


## REFERENCES

A. Books


1. Recommended Practices for GMAW Arc Welding (AWS code C5.6). Miami: American Welding Society, 1979.

2. Specifications for Welding of Sheet Metal (AWS code D9.1). Miami: American Welding Society, 1984.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Stress that keeping the nozzle clean and using correct ESO is very important in out-of-position welding. Remind students not to hammer guns on a table to clean out nozzles.

B. Suggested student activities

1. Use the buddy system in setting amperage and voltage--one student can read meters on welders while the other student welds.

## MODULE: GAS METAL ARC WELDING

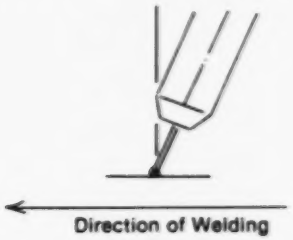
## UNIT IV: WELDING PRINCIPLES

## LESSON 1: BUILDING PADS OF BEADS

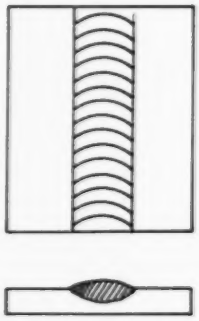
I. Basic GMAW techniques

A. Push technique (forehand)

1. Electrode points in the direction of welding



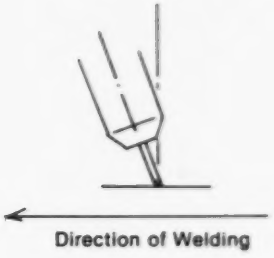

2. Push technique decreases penetration and gives a wider, flatter bead.



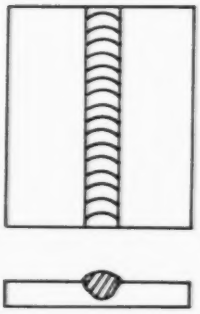
3. Push technique is mostly used on thick materials.

B. Pull technique (backhand or drag)

1. Electrode points opposite the direction of welding.



C. Alternate technique of ending a weld



1. Reverse the travel direction before breaking the arc.

2. After breaking the arc, keep the gun in place briefly so the crater will be shielded until it completely solidifies.

   NOTE: Using this technique is essential for welding out of corners where the weld has to start at a corner and be completed at a more accessible point.

II. Techniques for properly ending a weld

A. Just as in SMAW, end a weld properly by filling the crater.

   NOTE: In the job sheets that follow this unit, this part of the welding procedures is indicated with the phrase "crater and fill to end the weld."

B. Most common technique for ending a weld

1. Release the gun trigger just as the bead reaches the end of the weld.

2. Hold the gun in place and hesitate for just a second to keep the molten puddles covered with shielding gas.

3. Pull the gun away.

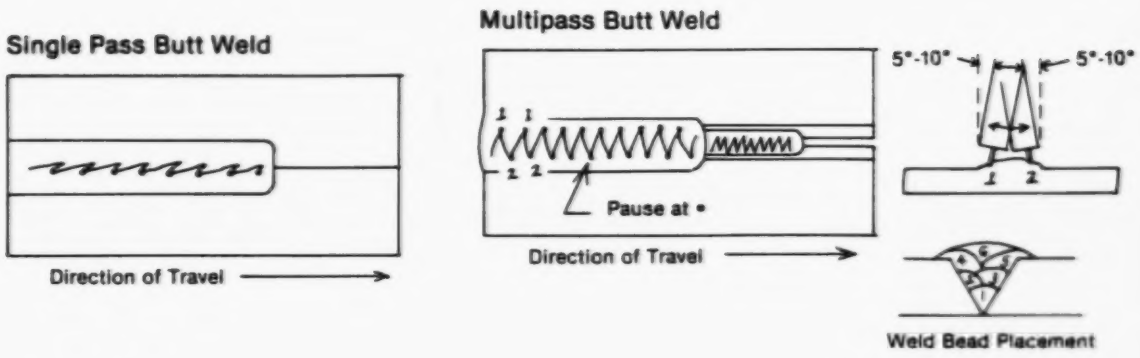
   NOTE: The slight hesitation after releasing the trigger is the key to making this method work because the burn-back control will continue action just long enough for the crater to fill and end the weld properly.

III. Position techniques and torch angles for GMAW

A. Flat

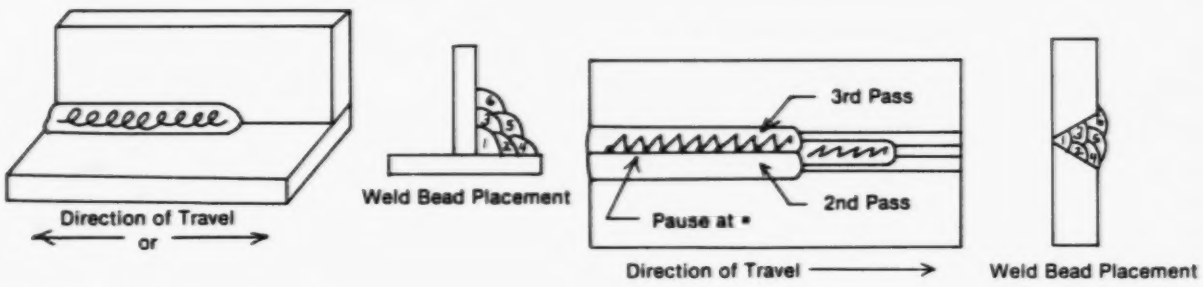
1. For single-pass butt joints, a slight back-stepping motion is preferred, while a small weave is preferred for a gaped butt joint.

2. For fill and cover passes, weave to desired width.



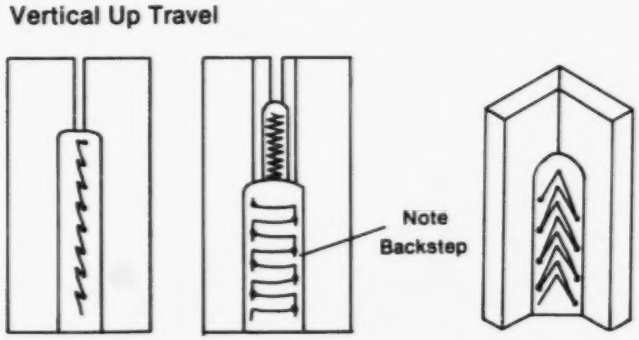

B. Horizontal

1. Fillet welds should be made with a circular weave, and butt joints use weaving to accomplish desired width.




C. Vertical up

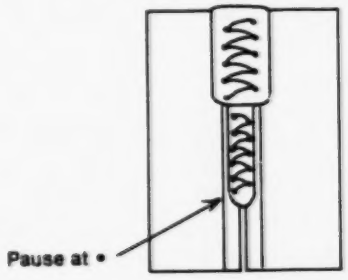
1. For both single and multi-pass butt and fillet welds, weaving is the best technique.



D. Vertical down

1. Requires special care to keep the arc on the leading edge of the puddle so the molten metal will not run around the arc and cause cold lapping.

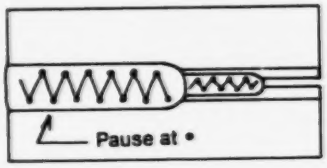
**Vertical Down Travel**




Remember to angle torch toward walls when weaving.

E. Overhead position

1. Use weaving for both butt joints and fillets.




Remember to angle torch toward walls when weaving.

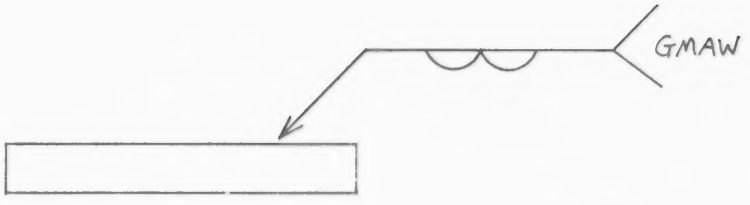
# BUILD PADS OF BEADS

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Mild steel, as selected by instructor
Wire-cutting pliers
Wire brush

Specifications:

Joint design and weld symbol



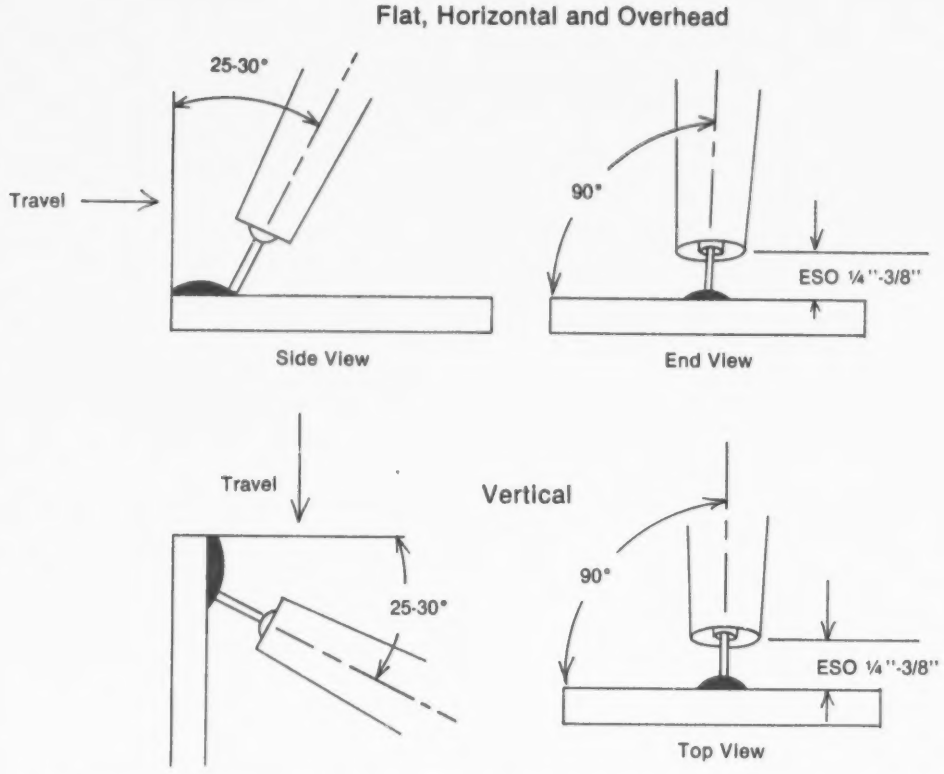

Wire: per instructor
Wire size: per instructor
Amp/lpm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DC + short arc
Position: flat, horizontal, vertical and overhead
Technique: push or pull
Cleaning: brush
Inspection: visual
Testing: N/A

Procedure:

1. Attach the flow meter regulator to the shielding gas as previously outlined and adjust flow rate. Complete equipment set-up as previously outlined.

2. Adjust controls for plate thickness and wire diameter. Position plate on work table.

3. Move gun down to plate and check gun angle and ESO.




4. Squeeze gun trigger and use a push or pull technique to lay the bead from left to right if right-handed, and right to left if left-handed.

   NOTE: The cups for guns are large enough that a good view of the weld zone will require that you position yourself so you can see to maintain the correct gun angle and ESO.

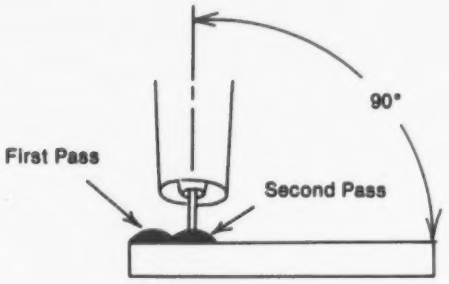
5. Weld bead the full length of the plate and crater and fill to complete the bead.

6. Release gun trigger. Place gun in a safe place.

7. Clean to specifications. Inspect for good penetration and fusion, uniform bead width and appearance, and defects such as excessive spatter and undercutting.

8. Ask instructor to check your work.

9. Check ESO for start of second bead and trim as required, but do not arc excess wire off on the side of the work table. Start second bead by repositioning gun angle so that second bead will overlap first bead as indicated.



End View

10. Pull the trigger and complete second bead. Clean and inspect each bead.

11. Ask instructor to check your finished pad.

12. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

INSTRUCTOR'S NOTE: By cutting a student's completed pad and polishing one cut edge, instructor and student alike can see the quality progression from beginning to end.

| Product Evaluation: | Evaluation 3 2 1 N |
|---|---|
| 1. Uniformity of bead or beads in multi-pass fillets | — — — — |
| 2. Evenness of chill/cooling rings | — — — — |
| 3. Amount of weight gain | — — — — |
| Average of above evaluations* | — — — — |

*This average is the student's final evaluation for competencies I10 through I13.

# MAKE FILLET WELD IN FLAT POSITION

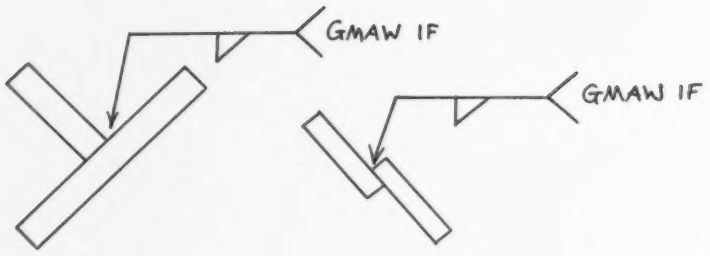
Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Mild steel as selected by instructor
Wire-cutting pliers
Wire brush

Specifications:

Joint design and symbol

Flat



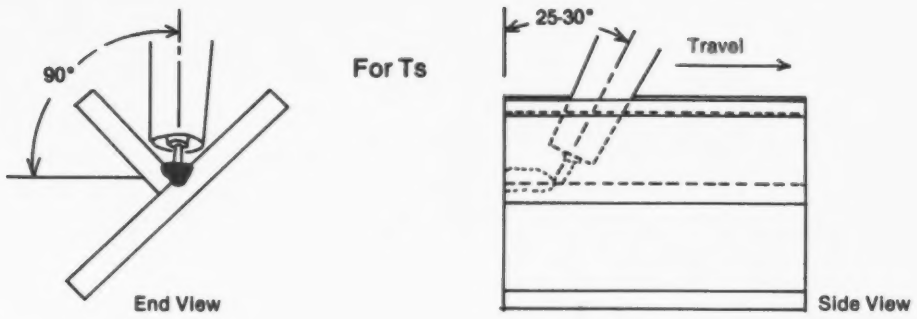

Wire: per instructor
Wire size: per instructor
Amp/Ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical DC+ short arc
Position: 1F
Technique: push or pull
Cleaning: brush
Inspection: visual

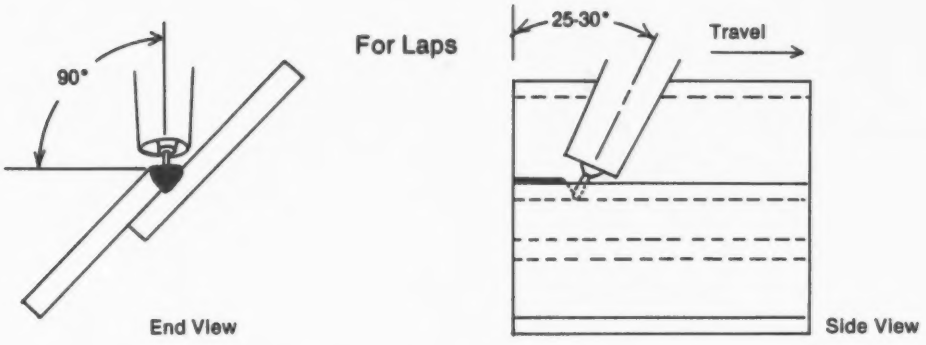
Procedure:

1. Attach the flow meter regulator to the shielding gas as previously outlined and adjust flow rate. Complete equipment set-up for short-arc transfer as previously outlined.

2. Adjust controls for plate thickness and wire diameter. Make a test bead on scrap metal and make required adjustments.

3. Position plates on work table and tack both ends of joint. Position plates in correct welding position. Position gun at correct angle to joint and check ESO.



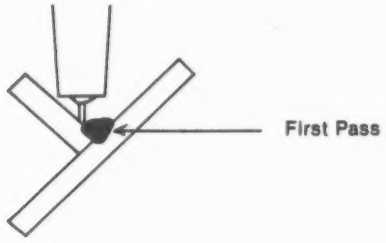

4. Squeeze gun trigger and use push or pull technique to weld the joint, being sure to position yourself so you can see to maintain correct gun angle and ESO.

5. Crater and fill to end of weld. Put gun in safe place.

6. Clean joint with wire brush as required. Inspect joint visually.

7. Check ESO for start of second bead and trim as required. Do not arc excess wire off on the side of the work table. Start second bead by repositioning gun angle so that second bead will overlap first bead as indicated.

Flat




8. Pull the trigger and complete the second bead.

9. Clean and inspect each bead and be sure succeeding beads overlap and fuse with the preceding beads and base metal.

10. Ask instructor to check your work.

11. Continue additional beads as directed by instructor.

12. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

INSTRUCTOR'S NOTE: By band-sawing Ts and laps across the weld, polishing and applying Lugols Solution (available from a pharmacist), the welding penetration can be easily seen.

| Product Evaluation: | Evaluation 3 2 1 N |
|---|---|
| 1. Unformity of bead or beads in multi-pass fillets | — — — — |
| 2. Evenness of chill/cooling rings | — — — — |
| 3. Amount of weight gain | — — — — |
| Average of above evaluations* | — — — — |

*This average is the student's final evaluation for competency I14: Make weld in 1F position with carbon steel--cored and solid wire.

# MAKE FILLET WELDS IN HORIZONTAL, VERTICAL AND OVERHEAD POSITIONS

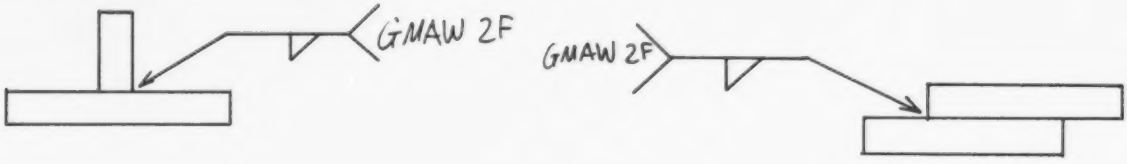
**Equipment:**

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Mild steel as selected by instructor
Wire-cutting pliers
Wire brush

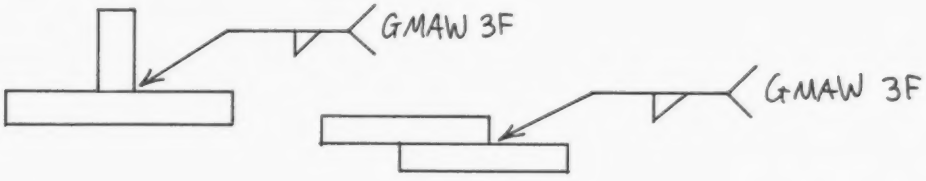
**Specifications:**

Joint design and symbol

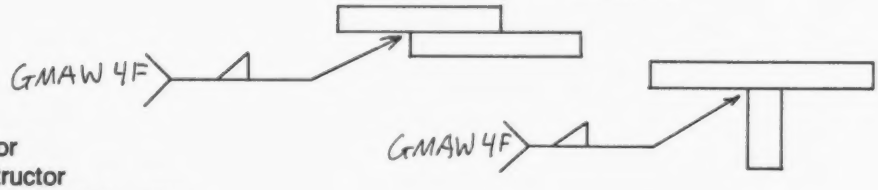
Horizontal




Vertical




Overhead




Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical DC+ short arc

| Position: | 2F | 3F | 4F |
|---|---|---|---|
| Direction of welding: | --- | Vertical up | --- |

Technique: Push or pull
Cleaning: brush
Inspection: visual
Testing: break

Procedure:

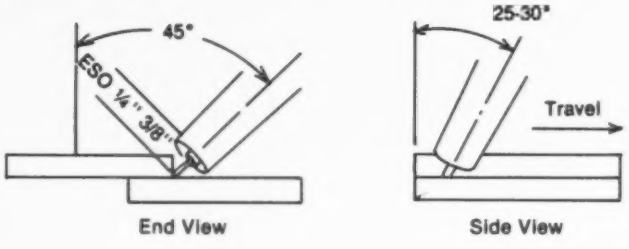
1. Attach the flow meter regulator to the shielding gas as previously outlined and adjust flow rate. Complete equipment set-up for short-arc transfer as previously outlined.

2. Adjust controls for plate thickness and wire diameter. Make a test bead on scrap metal and make required adjustments.

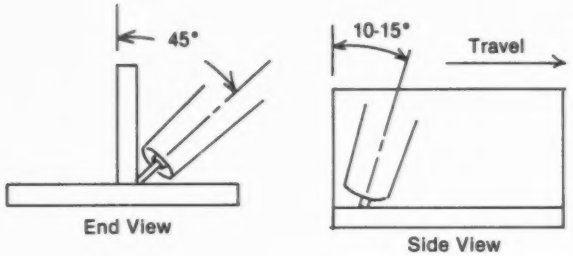
3. Position plates on work table and tack both ends of joint. Position plates in correct welding position. Position gun at correct angle to joint and check ESO.

**Horizontal**

For Laps

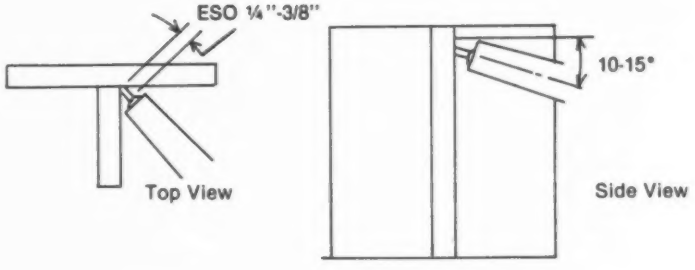



For Ts

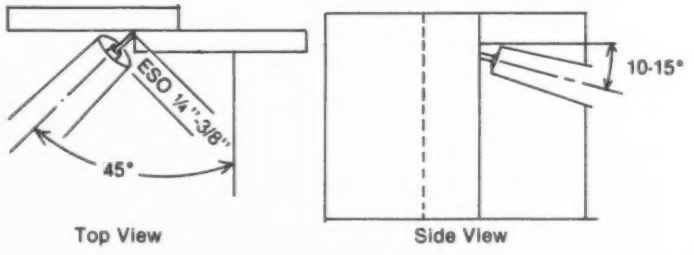



**Vertical**

For Ts

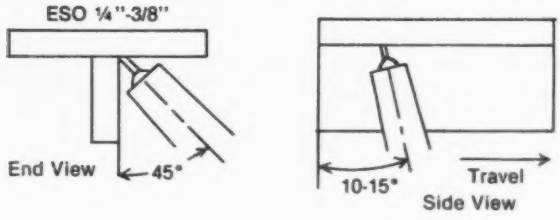



For Laps

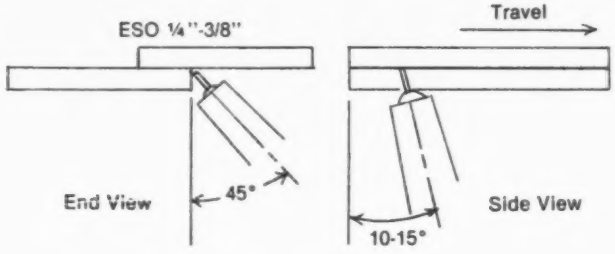


**Overhead**

For Ts




For Laps




4. Squeeze gun trigger and use push or pull technique to weld the joint, being sure to position yourself so you can see to maintain correct gun angle and ESO.

5. Crater and fill to end of weld. Put gun in safe place.

6. Clean joint with wire brush as required. Inspect joint visually.

7. Check ESO for start of second bead and trim as required. Do not arc excess wire off on the side of the work table. Start second bead by repositioning gun angle so that second bead will overlap first bead as indicated.

8. Take plates to vise and conduct a break test. Inspect break for good penetration and fusion or defects.

9. Take plates back to the work table. Retack both ends and weld other side of joint. Check and visually inspect joint.

10. Ask instructor to check your work.

11. Take plates back to vise and conduct another break test. Inspect break for good penetration and fusion or defects.

12. Ask instructor to check your work.

13. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

INSTRUCTOR'S NOTE: By band-sawing Ts and laps across the weld, polishing and applying Lugols Solution (available from a pharmacist), the welding penetration can be easily seen.

| Product Evaluation: | Evaluation 3 2 1 N |
|---|---|
| 1. Uniformity of bead or beads in multi-pass fillets | — — — — |
| 2. Evenness of chill/cooling rings | — — — — |
| 3. Amount of weight gain | — — — — |
| Average of above evaluations* | — — — — |

*This average is the student's final evaluation for competency I17, 20 and 21.

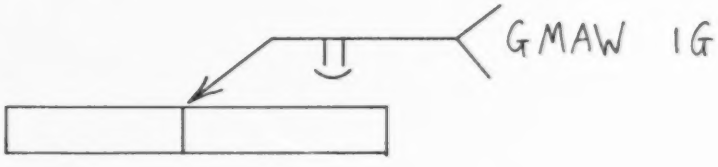
# WELD SQUARE GROOVE BUTT JOINT ON CARBON STEEL IN FLAT POSITION

Equipment:

GMAW machine and accessories
Personal safety clothing and equipment
Wire and shielding gas as specified
Carbon steel plates, as selected by instructor
Wire cutting pliers
Wire brush

Specifications:

Joint design and weld symbol




Wire: per instructor
Wire size: per instructor
Amp/Imp: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DCRP
Position: 1G
Technique: push
Cleaning: brush
Inspection: visual
Testing: bend (see Unit I)

Procedure:

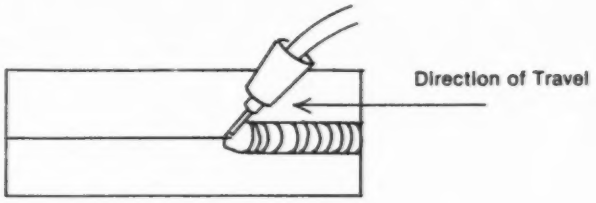
1. Prepare plates with 90-degree square edges.

2. Attach flow meter regulator to desired shielding gas cylinder manifold line. Complete equipment set-up as previously outlined.

3. Adjust controls for material thickness and wire size. Make a test bead on scrap metal and make required adjustments.

4. Position plates upside-down on work table and tack both ends of joint. (Make sure plates are in alignment.)

5. Turn plates over and position for welding in flat position. Position gun at correct angle to joint and check ESO.




6. Squeeze gun trigger. Form a puddle that fuses both edges of the joint. Push the gun forward while keeping the electrode on the leading edge of the puddle.

7. Crater and fill to the end of the weld and put gun in safe place.

8. Clean joint with wire brush as required. Inspect joint visually on face and root sides for complete penetration, fusion, bead uniformity and low spatter.

9. Ask instructor to check your work.

10. If approved by instructor, prepare specimens for bend test as previously outlined (Unit I).

11. Complete bend test and ask instructor to check bends.

12. Shut down equipment. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

| Product Evaluation: | Evaluation 3 2 1 N |
|---|---|
| 1. Unformity of bead or beads in multi-pass fillets | — — — — |
| 2. Evenness of chill/cooling rings | — — — — |
| 3. Amount of weight gain | — — — — |
| Average of above evaluations* | — — — — |

*This average is the student's final evaluation for competency I22: Make square butt weld in flat position with carbon steel--cored and solid wire.

## MODULE: GAS METAL ARC WELDING

## UNIT IV: WELDING PRINCIPLES

## UNIT TEST

**Choose the option which best answers the question or completes the statement.**

___ 1. How is a GMAW weld properly ended?

a. Just as in SMAW
b. The crater should be filled
c. Both a and b
d. None of the above

___ 2. Which is <u>not</u> a correct step for ending a weld?

a. Release the gun trigger just as the bead reaches the end of the weld.
b. Hold the gun in place and hesitate for at least a minute to keep the molten puddle covered with shielding gas.
c. Reverse the travel direction before breaking the arc.
d. After breaking the arc, keep the gun in place briefly so the crater will be shielded until it completely solidifies.

___ 3. The most common technique for ending a weld is to _____ .

a. Release the gun trigger just as the bead reaches the end of the weld; hold the gun in place and hesitate for at least a minute to keep the molten puddle covered with shielding gas; pull the gun away.
b. Reverse the travel direction before breaking the arc.
c. After breaking the arc, keep the gun in place briefly so the crater will be shielded until it completely solidifies.
d. b and c
e. None of the above

___ 4. For single-pass butt joints in the flat position, a slight _____ motion is preferred, while a _____ is preferred for a gaped butt joint.

a. Back-stepping, small weave
b. Circular, small weave
c. Back-stepping, circular motion
d. Circular, small weave

___ 5. For fill and cover passes in the flat position, use _____ to desired width.

a. Weaves
b. Stringer beads
c. Weaves and stringer beads
d. None of the above

___ 6. Fillet welds in the horizontal position should be made with a _____ weave.

a. Box
b. Lazy L
c. C motion
d. Circular

___ 7. For both single and multi-pass butt and fillet welds in the vertical upward position, the best technique is _____ .

a. A slow push
b. A fast push
c. Weaving
d. Backhand

___ 8. Welding in the vertical downward position requires special care to keep the arc on the _____ of the puddle so the molten metal will not run around the arc and cause cold lapping.

a. Trailing edge
b. Center
c. Left side
d. Leading edge

___ 9. In the overhead position, use _____ for both butt joints and fillet welds.

a. Back-stepping
b. Weaving
c. Stringer beads
d. Weaves and stringer beads

___ 10. With GMAW, keep contact tip and nozzle _____ and use anti-spatter gel as welding conditions require.

a. Clean and tight at all times
b. Ground to a sharp point
c. Reasonably clean and tight
d. Finger-tight

___ 11. Select the _____ size wire that can be used for a given application so deposition rate will be _____ .

a. Smallest, increased
b. Largest, increased
c. Smallest, decreased
d. Largest, decreased

____ 12. What is the most important rule to remember when adjusting current, volts, amperage or any electrical adjustments for GMAW?

a. Change variables in pairs.
b. Make radical changes in one variable at a time.
c. Change only one variable at a time.
d. Change only the amperage.

**List two characteristics of a good weld.**

13.

14.

**List five common welding mistakes.**

15.

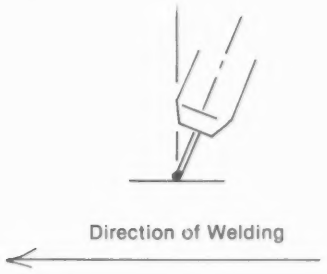
16.

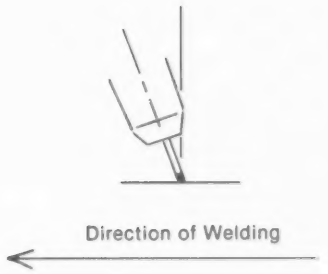
17.

18.

19.

**Identify basic GMAW techniques by placing the correct technique name below the appropriate illustration.**




20. _____ 21. _____

NOTE: Completion of this test to a specified score is necessary for the student to receive an evaluation on Job Sheets 2.1-2.3.

## ANSWERS TO UNIT TEST

1. c
2. b
3. e
4. a (I14)
5. a (I14)
6. d (I17)
7. c (I20)
8. d (I20)
9. b (I22)
10. a
11. b
12. c

13-14. Any two of the following:
Even ripple on bead
Slight crown on root
Well fused throughout joint

15-19. Any five of the following:
Cold lap
Excessive penetration
Insufficient penetration
Burn through
Surface porosity
Poor appearance
Whiskers
Bad tie-in
Suck-back
Improper ESO
Improper angle
Improper gas flow
Improper use of anti-spatter
Dirty nozzle
Failure to remove gas slag

20. Push

21. Drag or pull

## MODULE: GAS METAL ARC WELDING

## UNIT V: CARBON STEEL

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to make V-groove welds in various positions on carbon steel. The student should also be able to weld on carbon steel pipe in 5G and 6G positions. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

## SPECIFIC OBJECTIVES

1.1 Make groove welds on carbon steel in various positions.*

2.1 Make welds on carbon steel pipe in 5G and 6G positions.*

* Addresses competency on profile.

## MODULE: GAS METAL ARC WELDING

## UNIT V: CARBON STEEL

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: GROOVE WELDS ON CARBON STEEL

   a. Job sheet

      JS 1.1: Make groove welds in various positions

2. Lesson 2: WELDING ON CARBON STEEL PIPE

   a. Job sheet

      JS 2.1: Make welds on carbon steel pipe in 5G and 6G positions


## REFERENCES


A. Book

1. Sacks, J. Raymond. Welding Principles and Practices. Peoria, Ill.: Charles A. Bennett Co., Inc., 1976.

B. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Gas Metal Arc Welding and Flux-Cored Arc Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.


## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Make sure students learn to control weld puddle. Keep grooves wide enough to aid in full penetration. Remind students to clean finished passes before starting filler passes. Give them plenty of practice time with groove and pipe joints.

2. Use several different joint designs (square groove, $30^{o}$ single bevel, $30^{o}$ double bevel, $60^{o}$ V-groove, $60^{o}$ double V-groove). Have students perform both root and face bend tests.

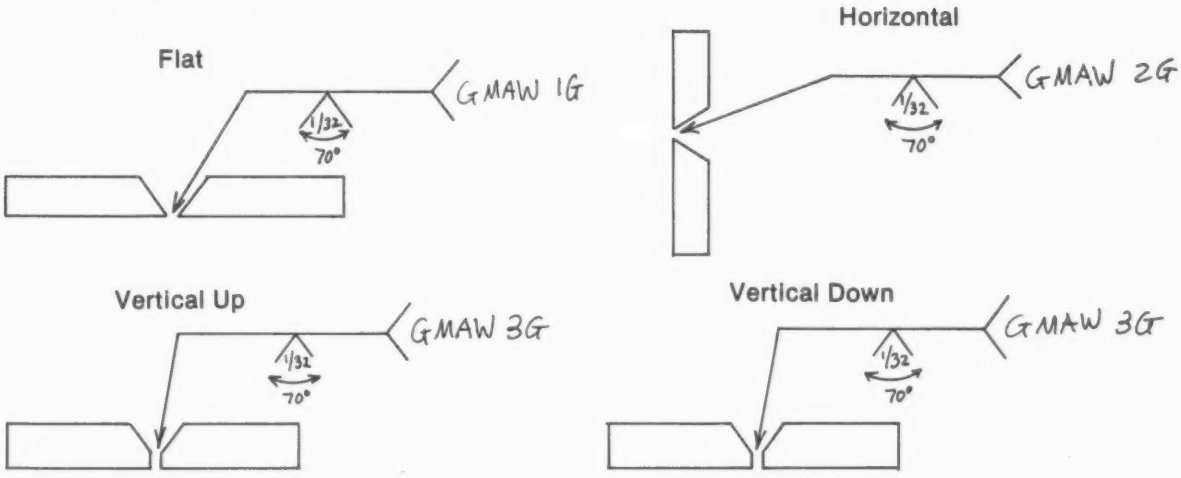
# MAKE GROOVE WELDS IN VARIOUS POSITIONS

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Mild steel as selected by instructor
Wire-cutting pliers
Wire brush

Specifications:

Joint design and weld symbols




Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DC+ short arc

| | | | | |
|---|---|---|---|---|
| Position: | 1G | 2G | 3G | 3G |
| Direction of welding: | | | Vertical up | Vertical down |

Technique: weave
Cleaning: brush
Inspection: visual
Test: bend (see Unit I)

Procedure:

1. Check work area to make sure it is free of flammable materials and is well ventilated, and note the location of the nearest fire extinguisher. Attach ground cable to workpiece.

2. Prepare plates with 35-degree bevels and grind edges to leave a 1/16" root.

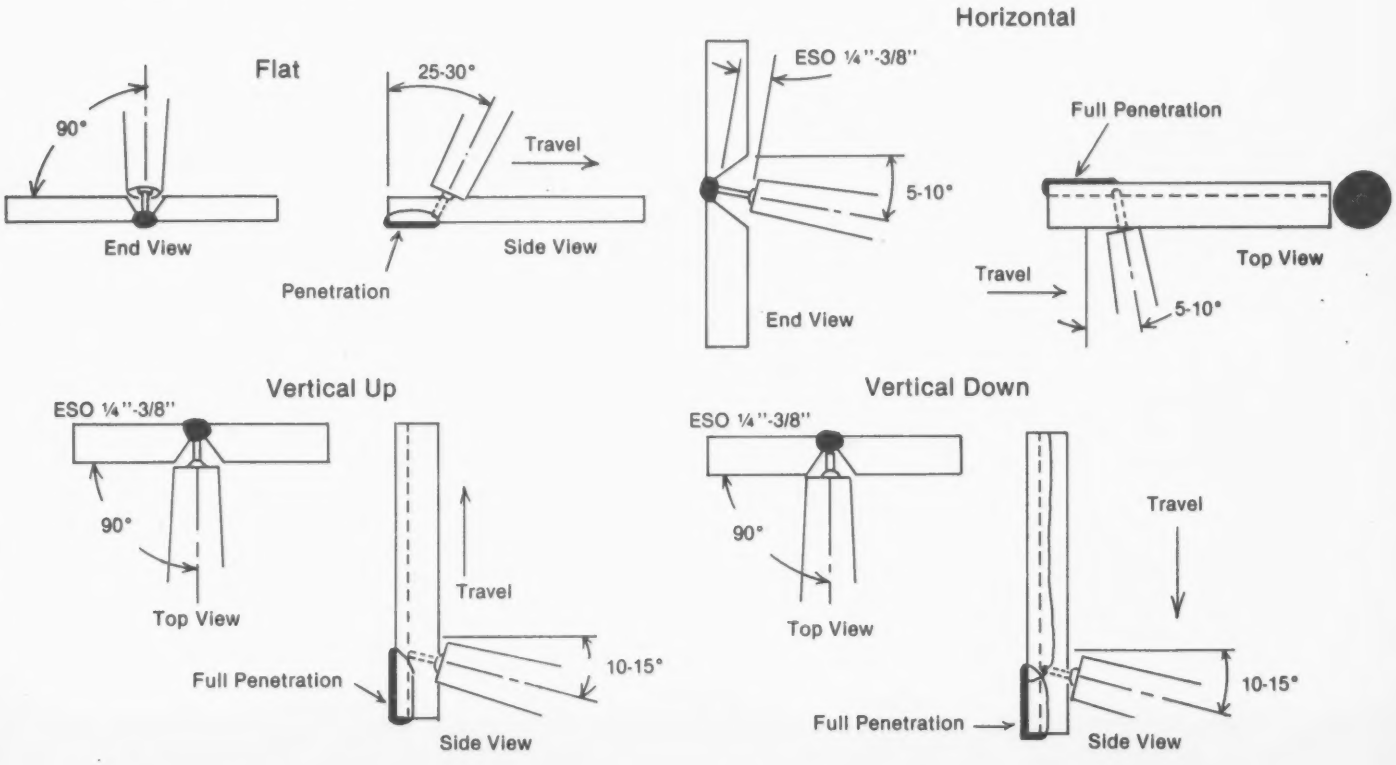
3. Attach the flow meter regulator to the shielding gas as previously outlined and adjust the flow rate.

4. Complete equipment set-up for short-arc transfer as previously outlined. Adjust controls for plate thickness and wire diameter.

5. Make a test bead on scrap metal and make required adjustments (Unit I).

6. Position plates upside-down on work table and tack both ends of joint, leaving 1/32" gap. (Gap will vary with metal thickness.)

7. Turn plates over and position for joint weld as specified. Position gun at correct angle to joint and check ESO.




8. Squeeze gun trigger and form puddle on one of the tack points so that it fuses with both edges of the joint. Use a slight crescent weave to completely fuse both sides of the root opening as you weld the length of the joint.

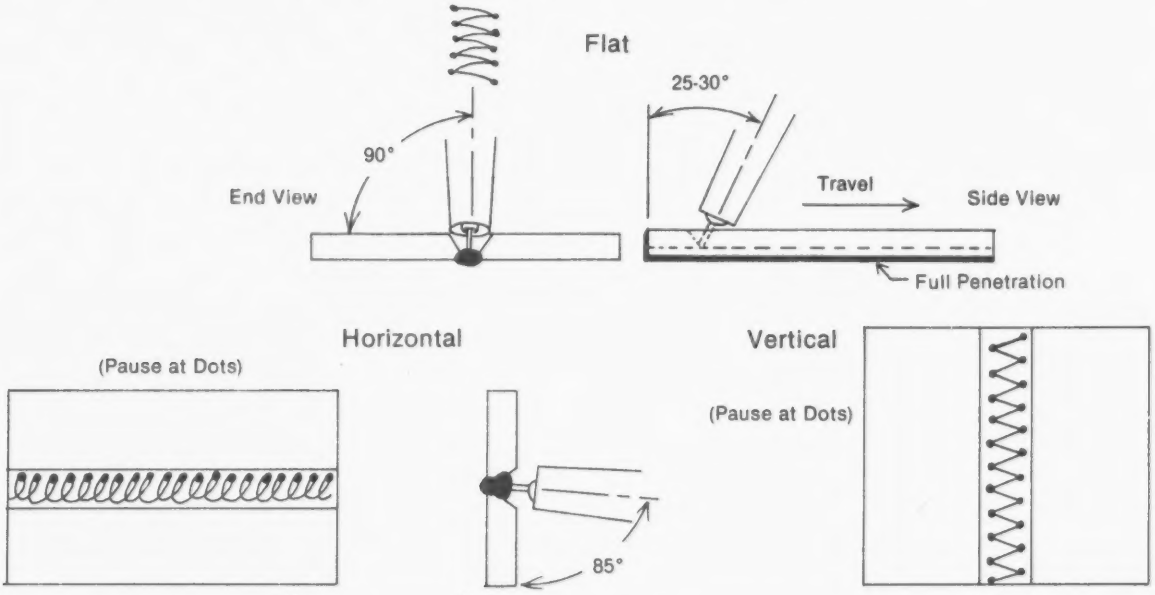
9. Crater and fill to end the weld. Put gun in a safe place.

10. Clean joint with wire brush as required. Inspect joint visually on front and back for complete penetration, good fusion, uniform bead width and minimum spatter.

11. Ask instructor to check your work.

12. Check ESO for start of fill-up bead and trim as required. Do not arc excess wire off on the side of the work table.

13. Reposition gun and use a weaving technique to lay a second pass over the first bead.




14. Crater and fill to end the weld. Put gun in a safe place. Clean and inspect second bead.

15. Ask instructor to check your work.

16. Continue running weave bead until enough beads have been laid down to fill the joint even with the surface of the base metal. Clean and inspect the final fill bead.

17. Ask instructor to check your work.

18. Check ESO for start of cap bead and trim as required. Reposition gun and use a weaving technique to place the cap pass over the joint.

19. Clean and inspect cap pass. Put the gun in safe place. Prepare specimens for bend test as previously outlined (Unit I). Complete bend test.

Procedure:

Evaluation
3 2 1 N

20. Ask instructor to check your work. — — — —

21. Shut down equipment. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

Product evaluation:

1. Uniform in width, chill rings, etc. — — — —
2. No defects, such as undercut or cold lap — — — —
3. Straightness of weld — — — —
4. Obvious penetration — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I25, I26, I27 and I28.

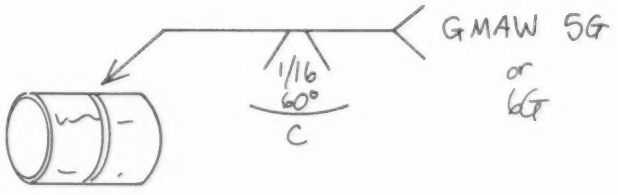
# MAKE WELDS ON CARBON STEEL PIPE IN 5G AND 6G POSITIONS

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire brush
Pliers
Portable grinder with wire brush
Straightedge
1/16" gap wire
6" schedule 40 pipe nipples
Electrode, as specified

Specifications:

Joint design and weld symbol




Electrical: DC+
Position: 5G (fixed)
Direction: vertical up
Technique: whipping and weaving
Cleaning: chip, brush and grind
Testing: bend (Unit I)

5G (fixed)
vertical down
whipping and weaving

6G
vertical up
whipping

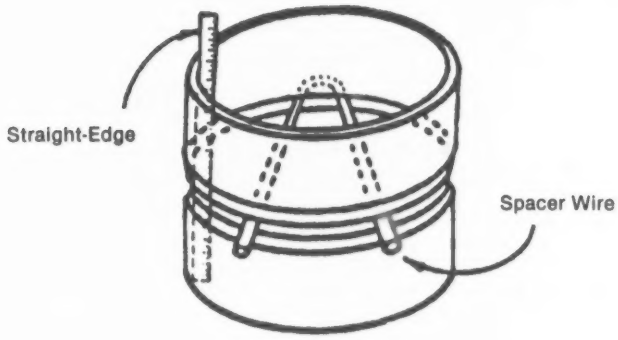
Procedure:

1. Check work area to make sure it is free of flammable materials and is well ventilated, and note the location of the nearest fire extinguisher. Attach ground cable to workpiece.

2. Select correct polarity for electrode. Turn on machine.

3. Put on welding helmet and adjust to correct amperage by running a test bead on scrap metal.

4. Place two 6" nipples on work table positioned so that one is on top of the other to form a vertical axis with a 1/16" gap wire placed between the two. Place a straight edge along the insides of the nipples and align them vertically.



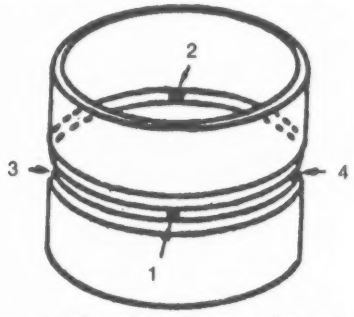

5. Tack weld the members in place according to the following procedure.

   a. Start between the spread ends of the gap wire and make the first tack weld.

   b. Move 180 degrees opposite the first tack weld; pull the gap wire out from between the two nipples. Use one end of the gap wire to recheck the gap at the point. Make the second tack weld.

   c. Move 90 degrees in either direction from the second tack weld and make the third tack weld.

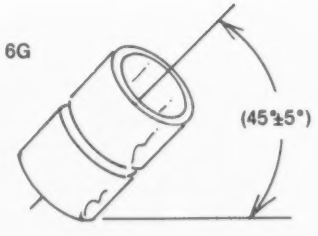
   d. Move 180 degrees opposite the third tack weld and make the fourth tack weld.



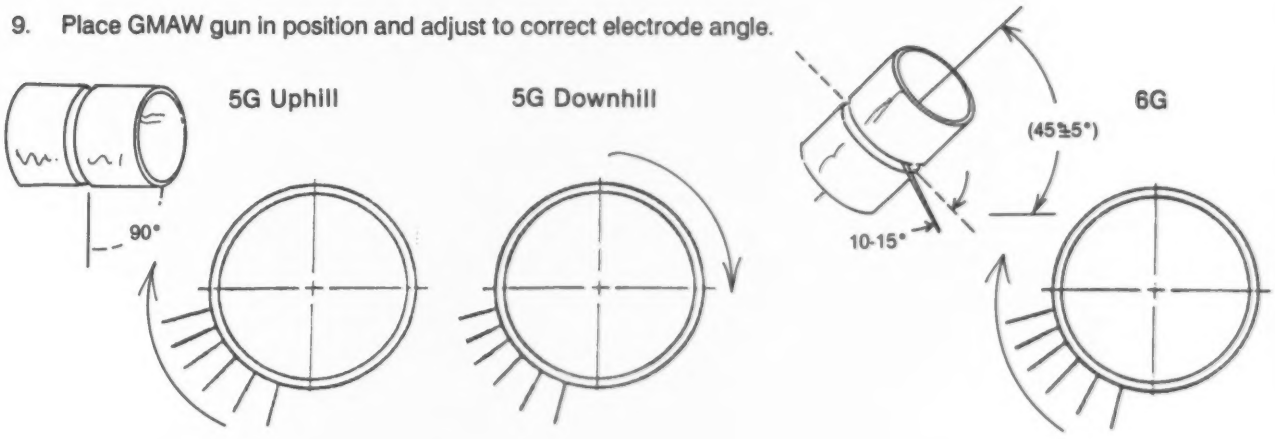

6. Feather all tack welds with a grinder, but be careful not to grind all the way through the tack weld.

| Procedure: | Evaluation 3 2 1 N |
|---|---|
| 7. Ask instructor to check your work. | — — — — |

8. Place the nipples so that they are in the position indicated in specifications.



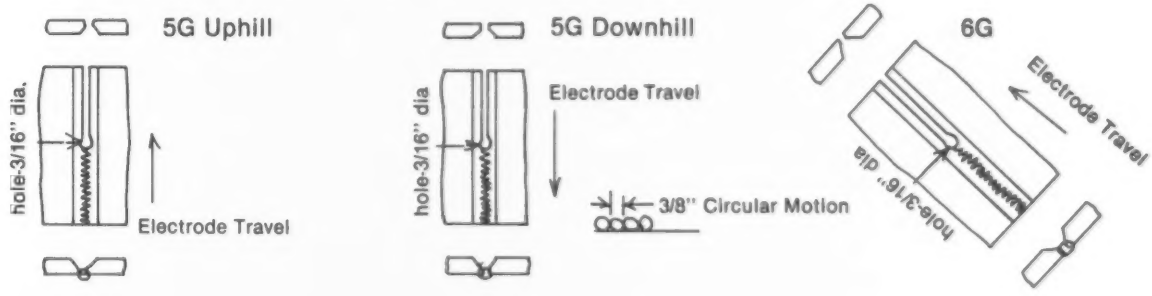
9. Place GMAW gun in position and adjust to correct electrode angle.




10. Strike an arc on one of the feathered tacks at the 3:00 (or 9:00) position and quickly adjust to proper arc length.

    **CAUTION:** Strike the arc only in the weld zone--not on the finished sides of the pipe.

11. Make a puddle and immediately form a keyhole.

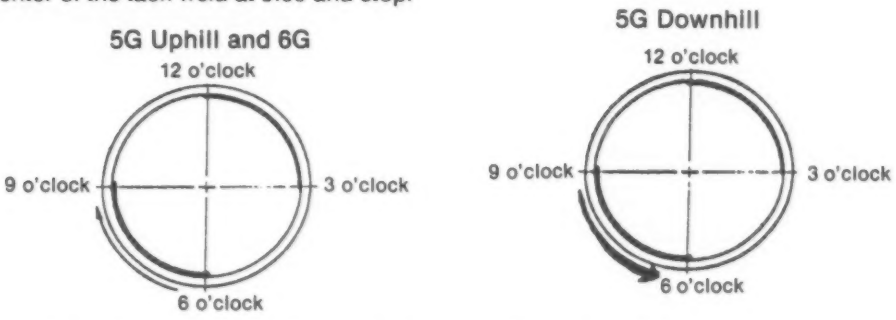



12. Whip the gun slightly forward to allow the keyhole to solidify. Then whip the gun back to deposit more metal in the keyhole.

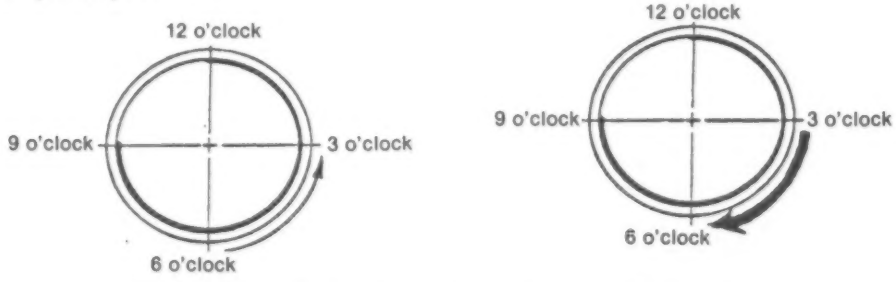
    NOTE: Do not deposit filler metal outside the keyhole as you whip the gun back and forth. Always move the gun back to the center of the keyhole. Keep electrode arching in the middle of the joint, not on the outer portion of the bevel.

13. Weld up to the center of the 12:00 tack weld and stop at the center point of the tack.

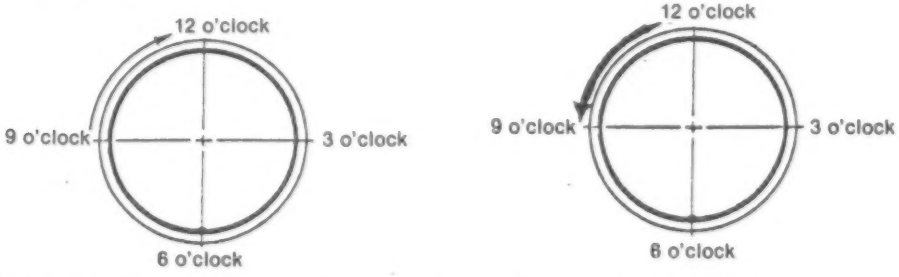
14. Restart arc at center of tack weld at 6:00. Form proper keyhole and weld up to the center of the tack weld at 9:00 and stop.




15. Go back to the tack weld at 6:00. Restart arc to tie in with previous quarter pass. Form proper keyhole and weld up to tack weld at 3:00 and tie in with first quarter pass.

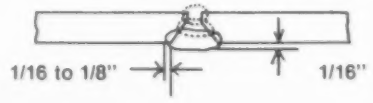



16. Go across to tack weld at 9:00. Restart arc to tie in with previous quarter pass. Form proper keyhole, and weld up to tack weld at 12:00 and tie in with the first quarter pass.




17. Brush or grind the entire stringer bead with a hand grinder. Inspect the root pass for good fusion and penetration and for defects such as undercutting on both outside and inside surfaces.

18. Lay a cap pass to finish the weld in vertical up welding from 6:00 to 12:00 on each side. Clean and inspect cap pass.




19. Ask instructor to check your work.

20. Shut down GMAW equipment. Conduct a bend test as outlined (Unit I).

21. Ask instructor to check your bend test. — — — —

22. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

Product evaluation:

1. Uniform in width, chill rings, etc. — — — —
2. No defects, such as undercut or cold lap — — — —
3. Straightness of weld — — — —
4. Obvious penetration — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I29, I30 and I31.

## MODULE: GAS METAL ARC WELDING

## UNIT VI: WELDING ON ALUMINUM

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to make welds on aluminum with spray transfer. This knowledge will be evidenced by completion of job sheets to specified score.

## SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student will be able to:

1.1 Utilize material presented in class to demonstrate the ability to:

a. Complete a fillet weld on aluminum.*

b. Make square butt weld in flat position with aluminum.*

*Addresses competency listed on profile

## MODULE: GAS METAL ARC WELDING

## UNIT VI: WELDING ON ALUMINUM

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

1. Lesson 1: FILLET WELD AND SQUARE BUTT WELD ON ALUMINUM

   a. Information outline

   b. Job sheets

      JS 1.1: Make fillet weld on aluminum
      JS 1.2: Make square butt weld in flat position with aluminum


## REFERENCES

A. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Gas Metal Arc Welding and Flux-Cored Arc Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Much of the material in the information sheets was presented earlier in Unit II; it is given here again as a quick review.

2. This is an appropriate time to hand out a chart that matches filler metal with base metal.

## MODULE: GAS METAL ARC WELDING

## UNIT VI: WELDING ON ALUMINUM

## LESSON 1: FILLET WELD AND SQUARE BUTT JOINT WELD ON ALUMINUM

I. Characteristics of spray-arc metal transfer

A. Metal transfer is made as a stream of tiny droplets moves across the arc from the electrode to the weld.

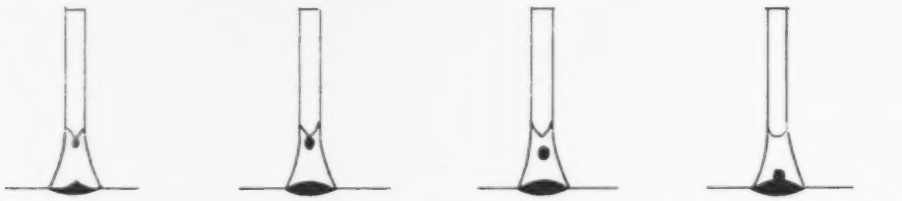
B. The process uses relatively high voltage and current; typical operating voltages range from 26-35 volts.

C. The spray-arc process has a characteristic sizzling or buzzing sound that usually indicates proper adjustment of all elements involved.

D. This process is used frequently with large-diameter wires or thicker metals.

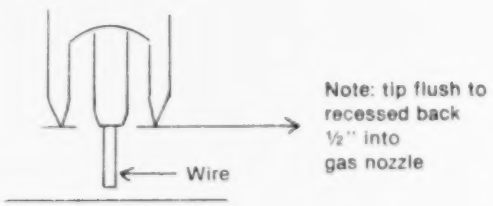
E. Specific gases are required.

F. The spray-arc process provides the fastest deposition of weld metal on aluminum and excellent deposition rates on thicker metals.



1. Droplet forming
2. Droplet being pinched off
3. Droplet in free flight
4. Droplet deposited

G. A normal ESO for spray-arc transfer is 3/4" to 1".




II. Rules of thumb for GMAW electrode wire selection

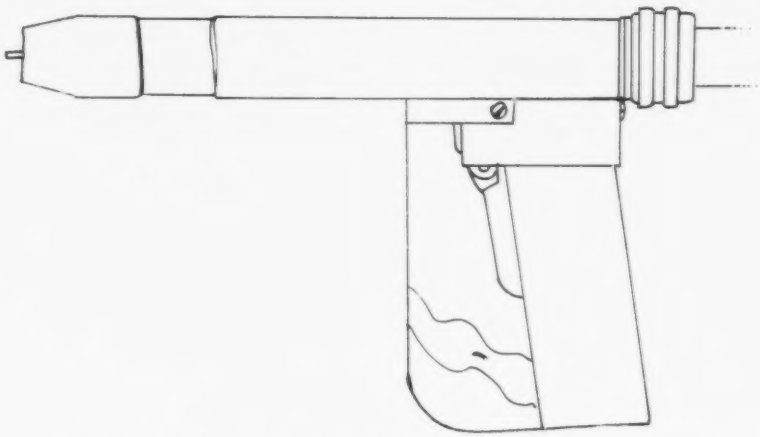
A. Solid electrode filler wires used for spray-arc transfer are larger diameter wires of .045", .68", 5/64", 3/32", 7/64", 1/8" or 5/32".

B. The composition of the electrode wire should match the composition of the base metal on which it will be used.

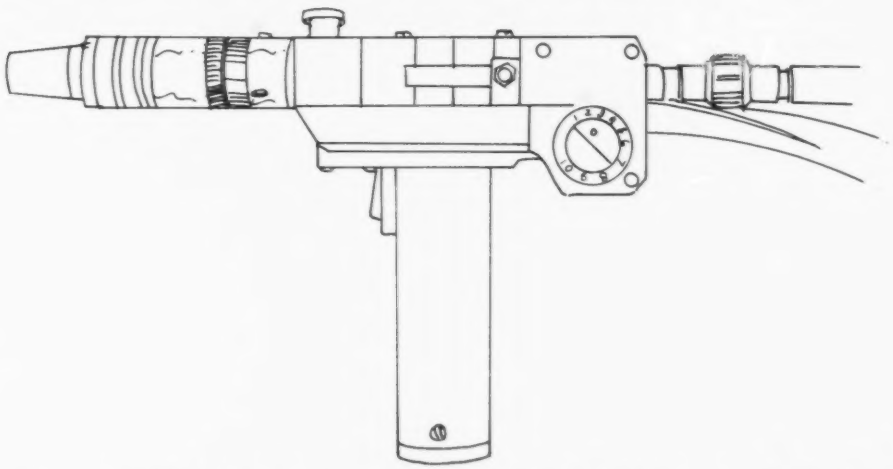
C. Since the objective of GMAW is to accomplish a high deposition rate at the lowest cost in materials and time, select the largest electrode size that can be used.

III. Types of GMAW guns used for spray transfer

A. Water cooled: Used in spray-arc transfer when the welding application requires long distance welds or weld times that are long, especially with larger diameter electrode

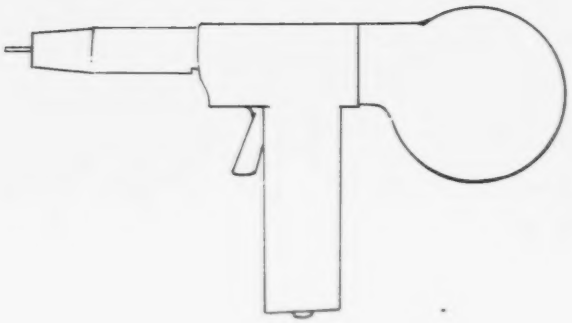


B. Push-pull: A gun with a small electric motor in the housing that pulls the wire from a spool or reel, then pushes it through the contact tips to the weld zone. This gun is used in situations where longer wire feed would drag or bind wire movement.



C. Spool gun (midget): A gun with housing capable of holding a small spool of wire and feeding it through the contact points. This gun is used primarily in welding aluminum with wire that is too soft to be pushed or pulled long distance.

NOTE: Both push-pull and spool guns have the amp/ipm control in the gun housing so it can be quickly adjusted by the operator.



IV. Basic GMAW shielding gases and uses

A. Argon, carbon dioxide ($CO_2$) and oxygen are the three basic GMAW shielding gases and are frequently used in combinations to accomplish specific GMAW applications.

B. Argon is the most frequently used shielding gas because it produces a clean, narrow bead with deep penetration on nonferrous metals in both spray-arc and short-circuit transfer.

C. $CO_2$ is far less expensive than other shielding gases. However, it can cause an unstable arc and produce spatter if not used carefully. $CO_2$ requires electrode wires with deoxidizing agents.

D. Oxygen is used in varying combinations with argon for both spray-arc and short-circuit transfer on both mild and stainless steel.

NOTE: Helium mixed with argon is used for some aluminum applications, but helium does not produce as stable an arc as argon.

V. Guidelines for welding aluminum

A. Adjust set-up for thickness of aluminum--thick sheets may need preheating, while thin ones may need backing.

B. Always push the gun when welding aluminum.

C. Remove oxide that forms at room temperature; bevel aluminum on a clean grinding wheel.

D. For boxes made of aluminum, use outside corner joints.

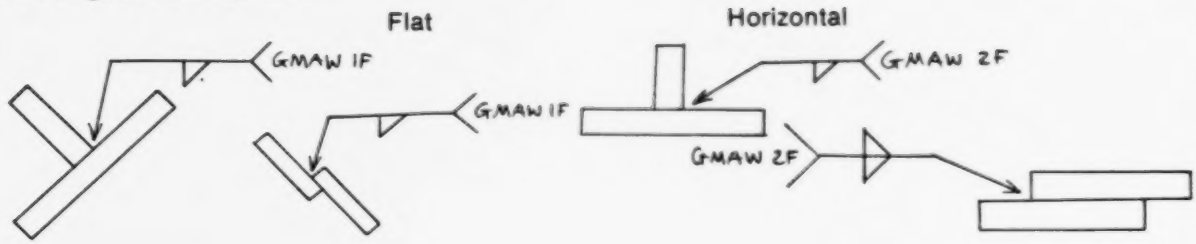
# MAKE FILLET WELD ON ALUMINUM

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Aluminum selected by instructor
Wire-cutting pliers
Stainless steel brush

Specifications:

Joint design and weld symbols

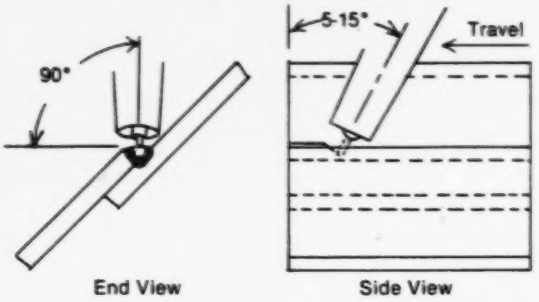



Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DC+ spray arc, moderate inductance, no slope
Position: 1F, 2F
Technique: push
Cleaning: stainless steel brush
Inspection: visual
Testing: N/A

| | | Evaluation 3 2 1 N |
|---|---|---|
| 1. | Attach flow meter regulator to the shielding gas as previously outlined and adjust flow rate. Complete equipment set-up for spray-arc transfer as previously outlined. | — — — — |
| 2. | Adjust controls for plate thickness and wire diameter. Make a test bead on scrap aluminum and required adjustments. | — — — — |
| | NOTE: Some machines have inductance and slope controls. If you are working with such a machine, a moderate setting of the inductance control should improve arc starting and help control spatter. No slope setting is needed in spray-arc transfer. | |
| 3. | Position plates on work table and tack both ends of joint. | — — — — |

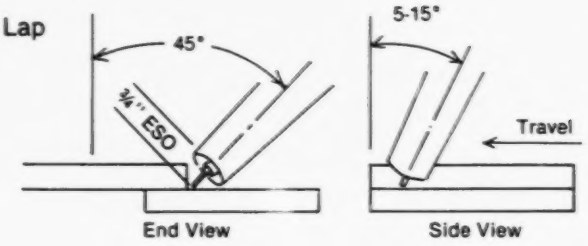
4. Place plates in correct welding position. Position gun at correct angle to joint end and check ESO. — — — —

Flat

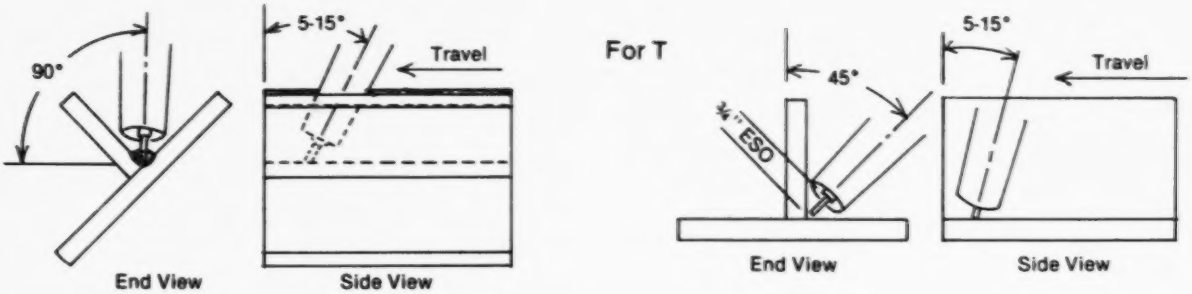



Horizontal

For Lap




For T




5. Squeeze gun trigger and use push technique to weld the joint, being sure to position yourself so you can see to maintain correct gun angle and ESO. — — — —

6. Crater and fill to end the weld. Put gun in a safe place. — — — —

7. Clean joint with stainless steel brush as required. Inspect joint visually. — — — —

8. Ask instructor to check your work. — — — —

9. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I15 and I18.

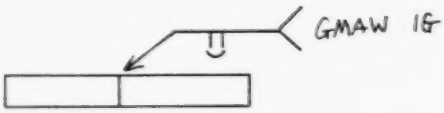
# MAKE SQUARE BUTT WELD IN FLAT POSITION WITH ALUMINUM

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Aluminum plates, as selected by instructor
Wire-cutting pliers
Stainless-steel brush

Specifications:

Joint design and weld symbol

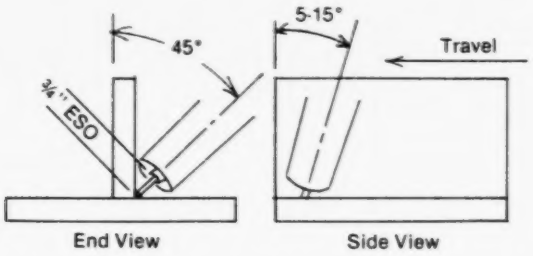



Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DCRP
Position: 1G
Technique: push
Cleaning: stainless-steel brush or chemical
Inspection: visual
Testing: bend (Unit I)

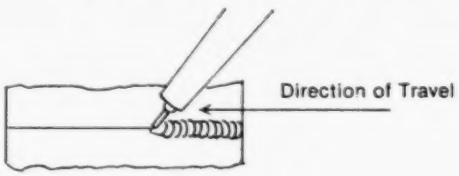
Procedure:

| | | Evaluation 3 2 1 N |
|---|---|---|
| 1. | Clean metal. Prepare and grind plates for 90-degree square edges. (Use grinding wheel that has not been contaminated by steel.) | — — — — |
| 2. | Attach flow meter regulator to the shielding gas cylinder or manifold line. Complete equipment set-up as previously outlined. Adjust controls for plate thickness and wire diameter. | — — — — |
| 3. | Make a test bead on scrap aluminum and required adjustments. | — — — — |
| 4. | Position plates upside-down on work table and tack both ends of joint, making sure plates are in alignment. | — — — — |

5. Turn plates over and position for welding in flat position. Position gun at correct angle to joint end and check ESO. — — — —




6. Squeeze gun trigger and form a puddle that fuses both edges of the joint. Push the gun forward while keeping the electrode on the leading edge of the puddle. — — — —




7. Crater and fill to end the weld. Put gun in a safe place. — — — —

8. Clean joint with wire brush as required. Inspect joint visually--face and root side--for complete penetration, fusion, bead uniformity and minimum spatter. — — — —

9. Ask instructor to check your work. — — — —

10. If approved by instructor, prepare specimens for bend test as previously outlined in Unit I. Complete bend test and ask instructor to check them. — — — —

11. Shut down equipment. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluation* — — — —

*This average is the student's final evaluation for competency I23: Make square butt weld in flat position with aluminum.

## MODULE: GAS METAL ARC WELDING

## UNIT VII: WELDING ON STAINLESS STEEL

## UNIT OBJECTIVES

Upon completion of this unit, the student should be able to make fillet welds and square butt joints on stainless steel. This knowledge will be evidenced by completion of job sheets to specified score.

## SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student will be able to:

1.1 Make fillet welds on stainless steel in flat and horizontal positions.*

1.2 Make a square butt weld in the flat position with stainless steel.*

*Addresses competency listed on profile

## MODULE: GAS METAL ARC WELDING

## UNIT VII: WELDING ON STAINLESS STEEL

## CONTENTS OF THIS UNIT


A. Objective sheet

B. Notes to the instructor

C. References

D. Lesson plan

1. Lesson 1: WELDING ON STAINLESS STEEL

a. Job sheets

JS 1.1: Make fillet welds on stainless steel in flat and horizontal positions
JS 1.2: Make square butt weld in flat position with stainless steel


## REFERENCES

A. Book


1. Sacks, J. Raymond. Welding Principles and Practices. Peoria, Ill.: Charles A. Bennett Co., Inc., 1976.


## NOTES TO INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Since metal for this unit is difficult to obtain, try to obtain usable stainless steel from industry that can be cut up with plasma, then sheared to coupon size.

2. Additional information on shielding gas used for stainless (usually trigon or a mixture) can be obtained from a local welding supplier.

3. Techniques

a. Correct heat setting is important so that stainless welds are not black colored.

b. Corner joints should be used in making tanks, depending on metal thickness for open or half-open corner.

c. A purging gas should be used on the back side of stainless joints wherever possible to prevent oxidation on the back side.

# MAKE FILLET WELDS ON STAINLESS STEEL IN FLAT AND HORIZONTAL POSITIONS

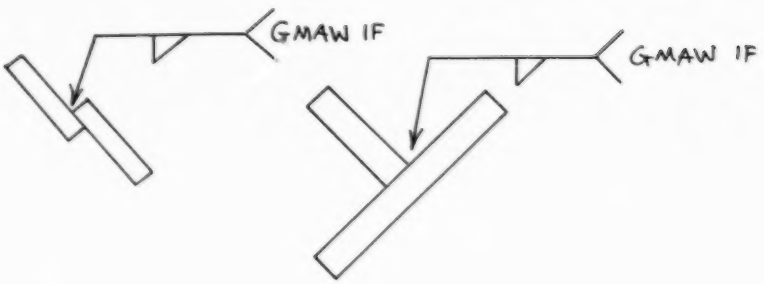
Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Stainless steel, as selected by instructor
Wire-cutting pliers
Bench vise
Hammer
Wire brush

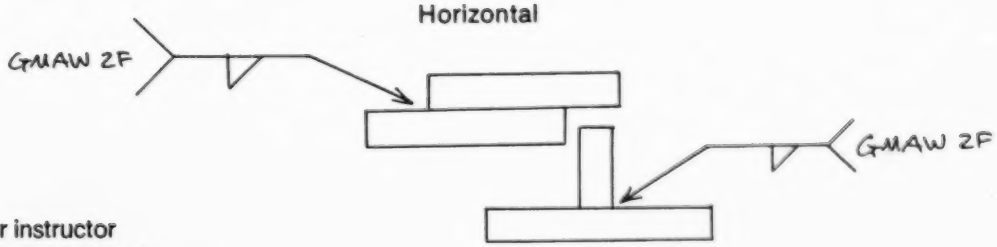
Specifications:

Joint design and weld symbols

Flat




Horizontal




Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DC+ short arc
Position: 1F, 2F
Technique: push or pull
Cleaning: brush
Inspection: visual
Testing: break

Procedure:

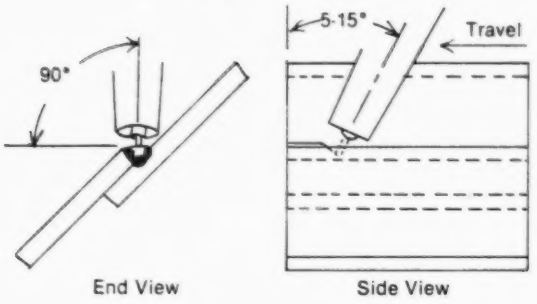
Evaluation
3 2 1 N

1. Attach the flow meter regulator to the shielding gas as previously outlined and adjust flow rate. Complete equipment set-up for short-arc transfer as previously outlined. — — — —

2. Adjust controls for plate thickness and wire diameter. Make a test bead on scrap metal and make required adjustments. — — — —

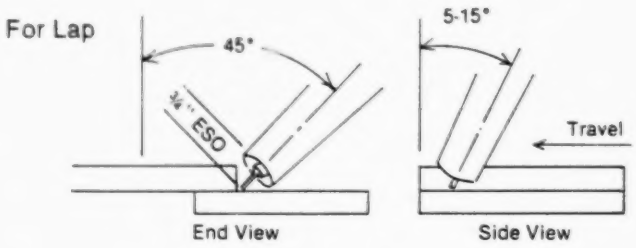
3. Position plates on work table and tack both ends of joint. Position plates in correct welding position. Position gun at correct angle to joint and check ESO. — — — —

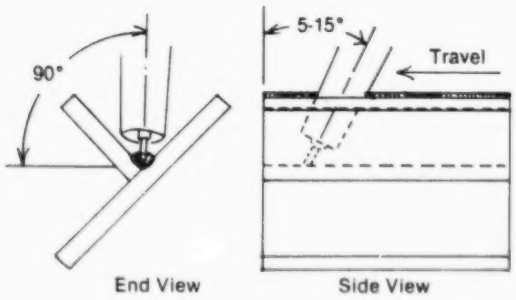
Flat



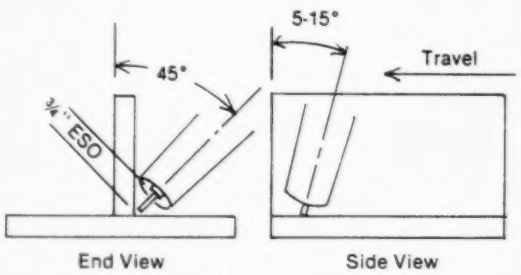

Horizontal

For Lap




For T




4. Squeeze gun trigger and use push or pull technique to weld the joint, being sure to position yourself so you can see to maintain correct gun angle and ESO. — — — —

5. Crater and fill to end the weld. Put gun in a safe place. — — — —

6. Clean joint with wire brush as required. Inspect joint visually. — — — —

7. Ask instructor to check your work. — — — —

8. Take plates to vise and conduct a break test. Inspect break for good penetration and fusion or defects. — — — —

9. Take plates back to the work table. Retack both ends and weld other side of joint. Clean and visually inspect joint. — — — —

10. Ask instructor to check your work. — — — —

11. Take plates back to vise and conduct another break test. Inspect break for good penetration and fusion or defects. — — — —

12. Ask instructor to check your work. — — — —

13. Shut down equipment. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This is the student's final evaluation for competencies I16 and I19.

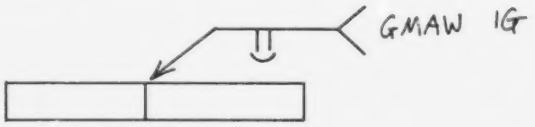
# MAKE SQUARE BUTT WELD IN FLAT POSITION WITH STAINLESS STEEL

Equipment:

GMAW machine with accessories
Personal safety clothing and equipment
Wire and shielding gas to specifications
Stainless steel plates, as selected by instructor
Wire-cutting pliers
Wire brush

Specifications:

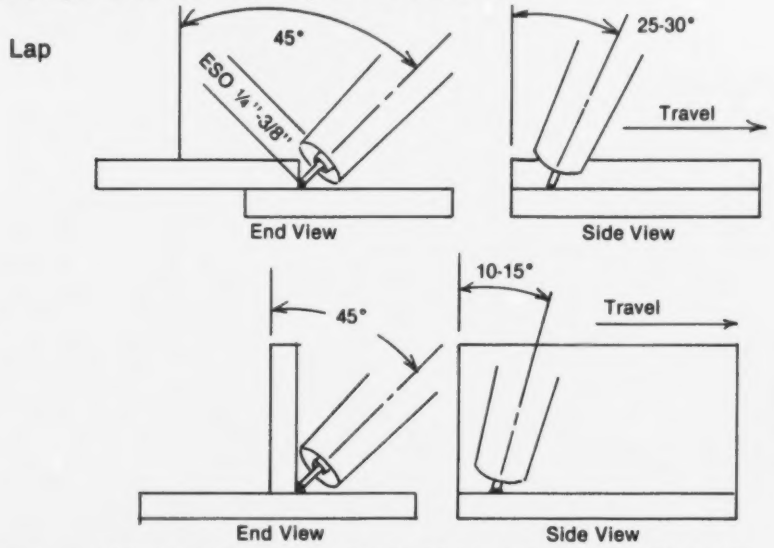
Joint design and weld symbol



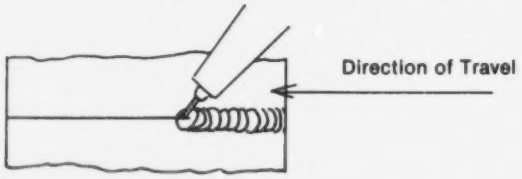

Wire: per instructor
Wire size: per instructor
Amp/ipm: to recommended setting
Shielding gas/flow rate: per instructor
Electrical: DCRP
Position: 1G
Technique: push
Cleaning: brush
Inspection: visual
Testing: bend (Unit I)

| Procedure: | Evaluation 3 2 1 N |
|---|---|
| 1. Prepare and grind plates for 90-degree square edges. | — — — — |
| 2. Attach flow meter regulator to shielding gas as previously outlined and adjust flow rate. Complete equipment set-up for short-arc transfer as outlined. | — — — — |
| 3. Adjust controls for plate thickness and wire diameter. Make a test bead on scrap metal and make required adjustments. | — — — — |
| 4. Position plates upside-down on work table and tack both ends of joint, making sure plates are in alignment. Turn plates over and position for welding in flat position. | — — — — |

5. Position gun at correct angle to joint and check ESO. — — — —




6. Squeeze gun trigger and form a puddle that fuses both edges of the joint. Push the gun forward while keeping the electrode on the leading edge of the puddle. — — — —




NOTE: If the electrode is allowed to arc anywhere but on the puddle's leading edge, the joint will have poor penetration and lack fusion.

7. Crater and fill to end the weld. Put gun in a safe place. Clean joint with wire brush as required. — — — —

8. Inspect joint visually--face and root side--for complete penetration, fusion, bend uniformity and minimum spatter. — — — —

9. Ask instructor to check your work. — — — —

10. If approved by the instructor, prepare specimens for bend test as previously outlined. Complete bend test and have instructor check bends. — — — —

11. Shut down equipment. Clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This is the student's final evaluation for competency I24: Make square butt weld in flat position with stainless steel.

## MODULE: GAS METAL ARC WELDING

## UNIT VIII: FLUX-CORED ARC WELDING

## UNIT OBJECTIVES

Upon completion of this unit, the student will be able to construct a pad of beads using flux-cored arc welding (FCAW) and make fillet welds in various positions using cored wire. This knowledge will be evidenced by completion of job sheets and the unit test to specified score.

## SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student will be able to:

1.1 Match FCAW and cored wire definitions to meanings.

1.2 Identify aspects of FCAW history.

1.3 Differentiate between FCAW advantages and limitations.

1.4 Identify benefits from learning FCAW.

1.5 List three pieces of FCAW equipment.

1.6 Match types of FCAW processes to definitions.

1.7 Identify FCAW electrode wire classifications.

1.8 Identify guidelines for using drive rolls and guide tubes.

1.9 Arrange steps in order for starting an arc with the semiautomatic process.

1.10 Determine effects of changing FCAW operating variables.

1.11 Identify FCAW preparations.

1.12 Determine proper FCAW general guidelines.

1.13 Demonstrate the ability to:

a. Build pads of beads in various positions using FCAW.*

b. Make fillet welds in various positions using cored wire.*

*Addresses competency on profile

## MODULE: GAS METAL ARC WELDING

## UNIT VIII: FLUX-CORED ARC WELDING

## CONTENTS OF THIS UNIT


A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: FCAW AND CORED WIRE

   a. Information outline

   b. Job sheets

      JS 1.1: Build pads of beads in various positions using FCAW
      JS 1.2: Make fillet welds in various positions using cored wire

E. Unit test

F. Answers to unit test


## REFERENCES

A. Curriculum guide

1. Fortney, Clarence, and Mike Gregory. Gas Metal Arc Welding and Flux-Cored Arc Welding. Stillwater, Okla.: Mid-America Vocational Curriculum Consortium, Inc., 1984.

## NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Flux-cored arc welding in vertical and overhead positions needs a more experienced student to run bead and joints.

2. Arc length is important, as well as travel speed. Keep reminding students that it will take practice to make good beads. Caution them against dragging the nozzle in molten metal.

B. Suggested supplemental materials

1. Sacks, J. Raymond. Welding Principles and Practices. Peoria, Ill.: Charles A. Bennett Co., Inc., 1976.

# MODULE: GAS METAL ARC WELDING

## UNIT VIII: FLUX-CORED ARC WELDING

## LESSON 1: FCAW AND CORED WIRE

I. Terms and definitions

A. FCAW (flux-cored arc welding)--an arc welding process where a weld is made by feeding a tubular, flux-filled, consumable electrode at a controlled rate into a weld joint (with or without the presence of a shielding gas)

B. Self-shielded--a flux-cored wire electrode that protects the weld zone from contaminants with fluxing elements released from the inner core of the wire as the arc is made

C. Dual-shielded--a flux-cored wire electrode used in the presence of a shielding gas to provide double protection and improved mechanical properties for the weld zone

D. Semi-automatic--a FCAW process where welding is controlled as an operator squeezes or releases a gun trigger

E. Automatic--a FCAW process where welding is controlled by mechanical devices programmed for specific applications

II. Brief history of FCAW

A. The FCAW process was developed because of the great potential offered by using a self-shielded electrode that can be mechanically fed from a continuous coil supply.

B. Early experiments with covered electrode, coiled and fed from a reel, were not successful because the flux covering tended to crack too easily.

C. In 1958, the Lincoln Electric Company introduced a process that turned the electrode wire "inside-out" so that the flux materials were inside a tubular wire.

D. Lincoln referred to their process as innershield and developed self-shielding electrode wire that permitted use of higher amperages and provided greater deposition rate for production-type applications.

III. Advantages and limitations of FCAW

A. Advantages

1. Gives greater deposition rates and can cut welding costs significantly

2. Eliminates the need for flow meters, shielding gases and piping components that other processes require

3. Helps eliminate the need for wind shielding; permits fan and ventilators to be used for added operator comfort in a shop when not used with a shielding gas

4. Can reach into places that can't be reached by other welding processes

5. Provides a one-process operation in both shop and field applications

6. Simplifies operator training, equipment selection and maintenance

B. Limitations

1. Process creates smoke in the work area

2. Clean up required after welding

IV. Benefits from learning FCAW

A. Introduces student to high deposition welding and provides practice with manipulative skills required for fast welding speeds

B. Provides student with basic skills needed for production-type welding

C. Gives student skills in a welding process that is relatively new, highly accepted by industry and likely to create jobs for those who master the process

V. Equipment required for semi-automatic self-shielded FCAW

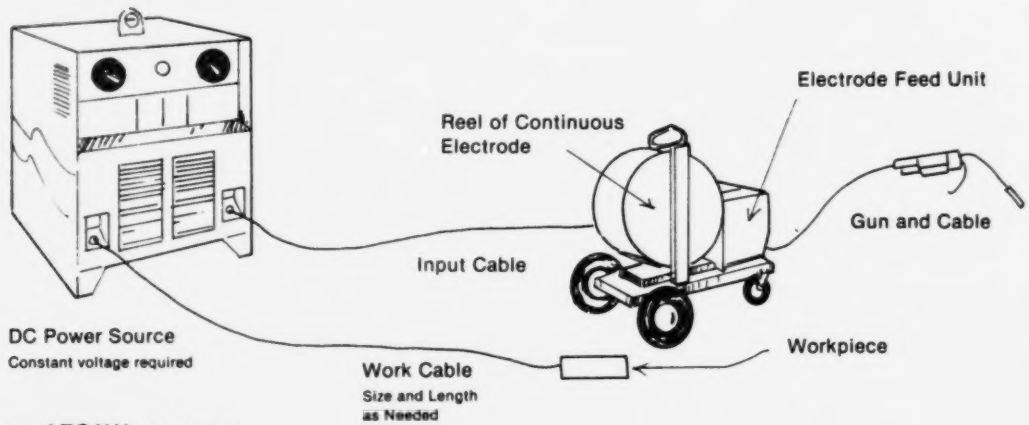
A. A constant voltage DC power source with a minimum amperage range of 200-400 amps

B. Electrode input cable

C. Reel of continuous electrode wire

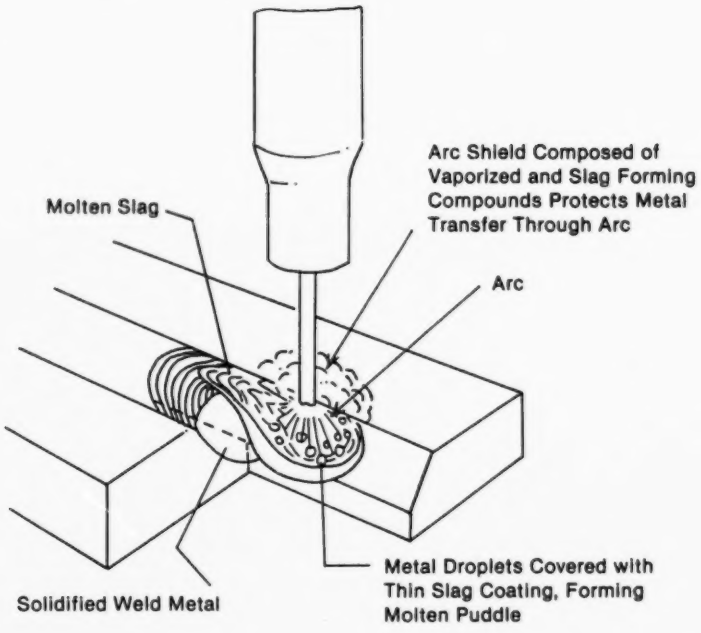
D. Electrode feed unit

E. Work cable and ground




VI. Types of FCAW processes

A. Semi-automatic self-shielded: a modification of the manual shielded metal-arc welding process; the covered SMAW electrode is replaced with a continuous flux-cored electrode that is fed through a gun instead of an electrode holder


Arc Shield Composed of Vaporized and Slag Forming Compounds Protects Metal Transfer Through Arc
Molten Slag
Arc
Metal Droplets Covered with Thin Slag Coating, Forming Molten Puddle
Solidified Weld Metal

1. Guns for self-shielded process

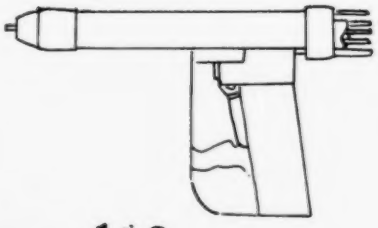
   a. Straight nozzle: used mostly for fillet welds and on applications where the work flows under the gun

   b. Curved nozzle: used mostly for welding heavy metals because of improved flexibility and easy manipulation. It requires heavy-duty, wire-drive units.

2. Guns for gas-shielded process

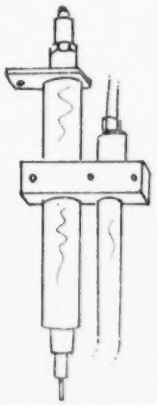
   a. Air cooled

   b. Water cooled

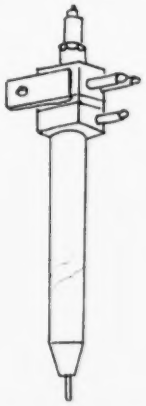


B. Automatic self-shielded: a modification of the semiautomatic self-shielded process that replaces manual manipulation with programmed, mechanized components.

1. Air cooled FCAW guns



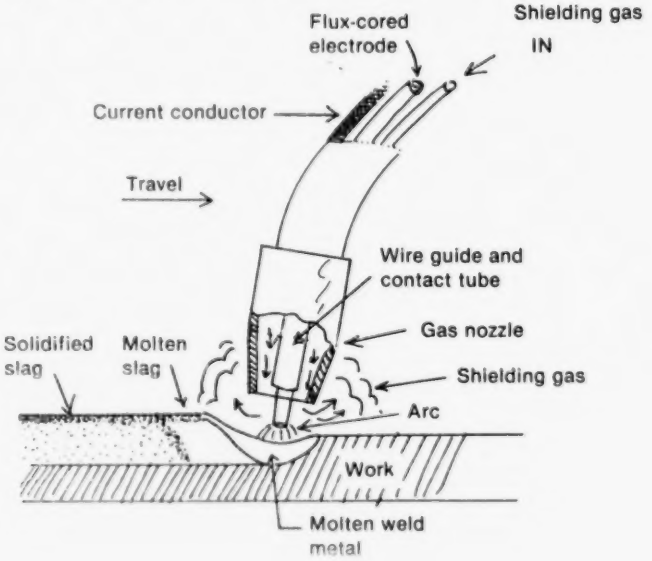
2. Water cooled FCAW guns



C. Dual-shielded flux cored: a welding process similar to both SMAW and GMAW

1. Different from SMAW in that $CO_2$ is usually used as a shielding gas in a dual function with the electrode flux

2. Different from GMAW in that the electrode wire is tubular instead of solid




VII. FCAW electrode wire

A. Classification

1. As with other AWS electrode classifications, the introductory "E" means electrode.

2. The second two digits indicate the tensile strength and welding position.

4. Final numbers or number-letter combinations indicate any special chemical composition of the wire.

5. The "T" and following number indicate whether or not the electrode is to be used as self-shielded or dual-shielded.

   a. Self-shielded: All T-3, T-4, T-6, T-7, T-8, T-9 and T-10 electrodes are in this class.

   b. Dual-shielded: All T-1, T-2 and T-5 electrodes are in this class.

6. The T-3, T-4 and T-6 electrodes are designed for DCRP operations with fast wire-feed speeds and high amperage for high deposition welding.

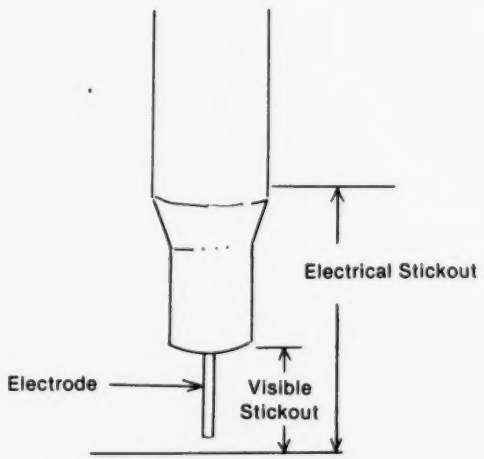
7. Other T-series electrodes are designed for DCSP for slower wire-feed speeds and lower amperages, but still provide fast travel and good penetration for special applications.

8. Other classifications include T-G, which covers multi-pass electrodes not covered under specific classifications, and T-GS, which covers single-pass electrodes of the same category.

B. ESO and VSO

1. ESO (electrical stickout): the length of the electrode from the workpiece to the contact tip within the nozzle

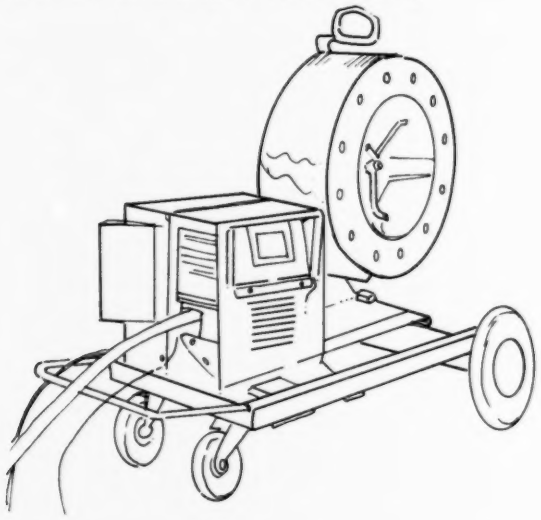
2. VSO (visible stickout): the length of the electrode that can actually be seen between the end of the nozzle and the workpiece



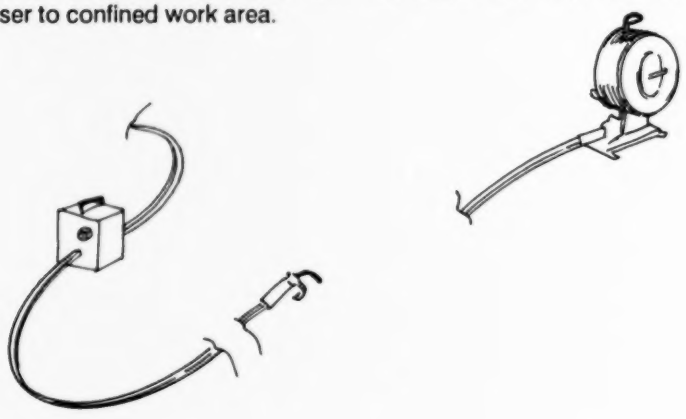

NOTE: When the contact tip and the end of the nozzle terminate at the same point, ESO and VSO are the same.

C. Basic types of flux-cored wire feeders

1. Integrated: Drive-roll and control unit are attached to the wire reel housing. The entire unit is mounted on a dolly for added mobility.



2. Remote: Drive-roll and control unit are detached from the wire reel housing so longer work-to-electrode distances can be used and the control unit can be moved closer to confined work area.



VIII. Guidelines for using drive rolls and guide tubes

A. Drive rolls and guide tubes for wire feeders have the wire sizes for which they are designed stenciled on them and should be used only for that wire size.

B. Drive rolls and guide tubes should be cleaned after each roll of wire electrode is used.

C. Remove accumulated dirt and shavings with a wire brush. Do not use a solvent to clean drive rolls.

D. Some worn drive rolls can be reversed, but usually badly worn ones should be replaced.

E. When drive rolls slip while wire is being fed into cable, it indicates the end of the wire has not been properly prepared or shavings have probably built up in the cable.

IX. Techniques for starting an arc with the semiautomatic process

A. Inch the electrode out beyond the nozzle to just short of the visible stickout recommended for the electrode size and guide tip.

B. Cut the end of the wire.

C. Position the tip of the electrode just off or just barely touching the base metal.

D. Squeeze the trigger to start the arc, but do not push the electrode into the joint as it starts to burn away.

E. Allow the arc to establish itself fully. Then slowly pull the gun back until the recommended stickout is established.

F. Even when a long stickout is desired, start with about 1/2" of visible stickout. Establish the arc as outlined. Then increase the stickout to the desired length.

X. Operating variables with flux-cored electrode wires

NOTE: The effects listed under each variable assume that all other variables are held constant.

A. Arc voltage

1. High arc voltage will produce a wider and flatter bead.

2. Excessive arc voltage tends to produce porosity.

3. Low voltage tends to produce a convex, ropy bead.

4. Extremely low voltage will cause the wire to stub or pierce the plate, strike the joint bottom and push the gun up.

B. Current

1. Increasing current increases melt-off and deposition rate.

2. Excessive current produces a convex bead that looks bad and wastes metal.

3. Low current results in reduced penetration.

C. Travel speed

1. Excessive travel speed makes the bead concave with uneven edges.

2. Too slow a travel speed produces slag inclusions and a rough, uneven bead.

D. Electrical stickout

1. Increased stickout decreases current; decreased stickout increases current.

2. Increased stickout lowers voltage across the arc. The lower arc voltage makes the bead more convex, and the tendency for porosity is reduced.

3. Short stickout gives greater penetration than long stickout.

XI. FCAW preparations

A. Clean the joint of scale, rust, paint, oil, grease and moisture since clean surfaces help reduce porosity and make possible the faster welding speeds important for FCAW.

B. When making tack welds, use the same electrode recommended for the application.

C. Clamp the work cable to the workpiece so that there is good metal-to-metal contact.

NOTE: Good grounding is essential. Machine meters may indicate proper voltage when a bad ground is causing convex or ropy beads that are typically the result of low voltage.

D. Try different locations for the ground clamp to obtain the best weld quality.

E. Never use undersized or badly worn cables.

XII. General guidelines for FCAW

A. Semi-automatic FCAW

1. In most applications, a good bead shape can be obtained by using the highest voltage possible without causing porosity.

2. Always increase voltage with current to maintain a good bead shape.

3. Remember that travel speed is almost always faster with self-shielded flux-cored electrodes than with stick electrodes because of the high deposition rate.

NOTE: Beginners with the semi-automatic FCAW process almost always use a travel speed that is too slow.

B. Safety requirements

1. Personal safety clothing and equipment should be used when working with FCAW equipment.

2. Procedures for safely operating machines and electrical components should be followed at all times.

3. Working with flux-cored wires, especially in confined areas, may produce excessive smoke and fumes that require special ventilation or the use of a welding gun with a smoke-removal attachment.

4. Sparks generated by the FCAW process can be excessive and erratic and require that the entire welding area be screened from nearby workers or passers-by.

**CAUTION:** When using spray-transfer, check with instructor for proper lens due to arc brightness.

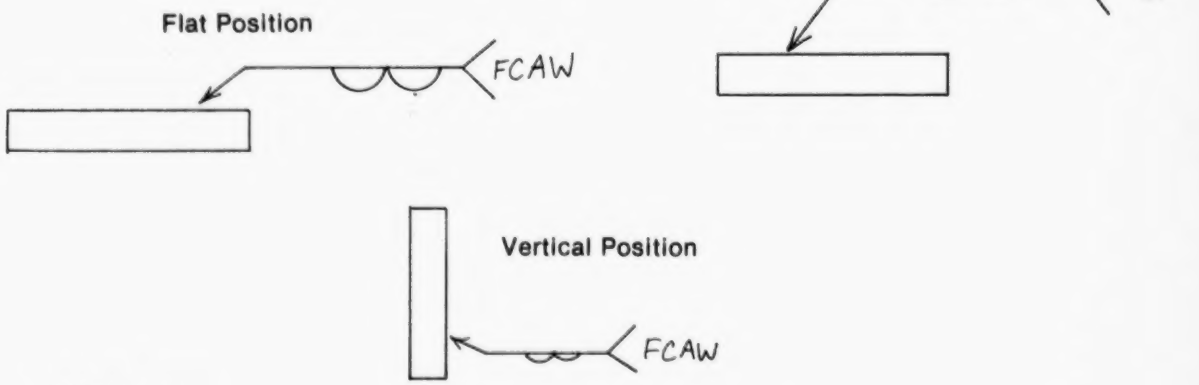
# BUILD PADS OF BEADS IN VARIOUS POSITIONS USING FCAW

Equipment:

FCAW machine and accessories
Personal safety equipment and clothing
Wire and shielding gas as specified
Mild steel, as selected by instructor
Wire cutting pliers
Wire brush
Chipping hammer

Specifications:

Joint design and weld symbols

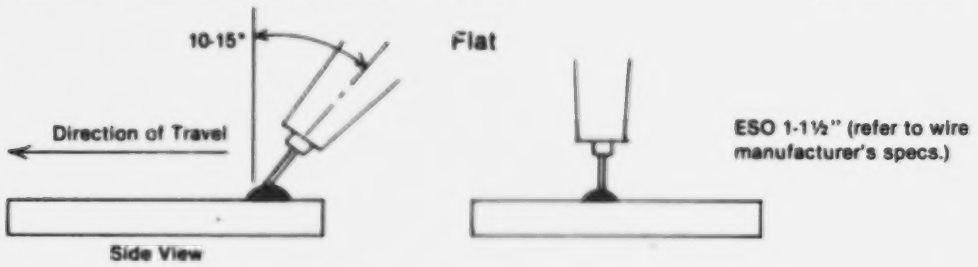


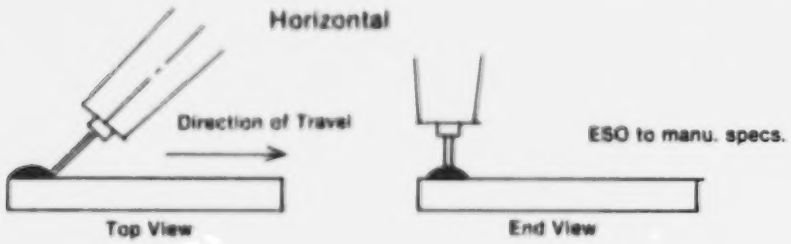

Wire: per instructor
Wire size: per instructor
Amp/ipm: to manufacturer's recommendation
Shield gas/flow rate: per instructor
Electrical: to manufacturer's recommendation
Positions: flat, horizontal and vertical
Technique: push or pull
Cleaning: chipping hammer and brush
Inspection: visual
Testing: N/A

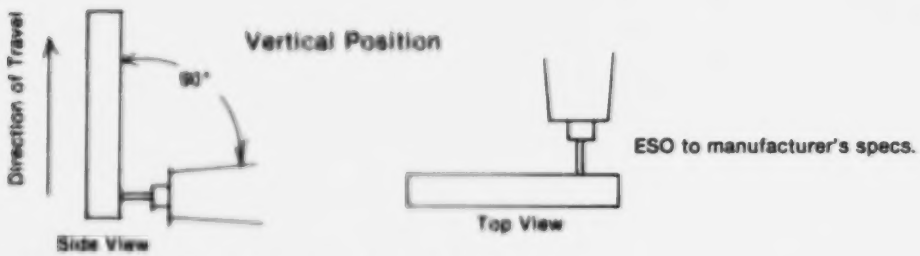
Procedure:

| | | Evaluation 3 | 2 | 1 | N |
|---|---|---|---|---|---|
| 1. | Attach the flow meter to the shielding gas as previously outlined and adjust the flow rate. Complete equipment set-up as previously outlined. | — | — | — | — |
| 2. | Adjust controls for plate thickness and wire diameter. Position plate on work table. | — | — | — | — |

3. Move gun down to plate and check gun angle and ESO. — — — —




4. Squeeze gun trigger and use a push or pull technique to lay the bead from left to right (if right-handed) or from right to left (if left-handed). — — — —

NOTE: The cups of guns are large enough that a good view of the weld zone will require you to position yourself so you can see to maintain the correct gun angle and ESO.

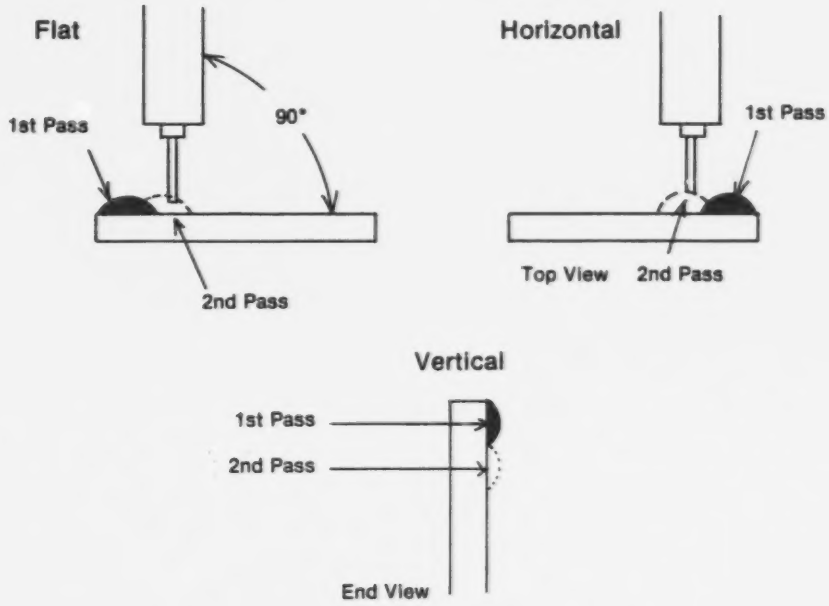
5. Weld bead the full length of the plate and crater, filling to complete the bead. — — — —

6. Release gun trigger and put gun in a safe place. — — — —

7. Clean bead to specifications. Inspect for good penetration and fusion, uniform bead width and appearance, and defects such as excessive spatter and undercut. — — — —

8. Ask instructor to check your work. — — — —

9. Check ESO for start of second bead. Trim as required. (Do not arc excessive wire off on side of the work table.) Start second bead by repositioning gun angle so second bead will overlap first as indicated. — — — —




10. Pull trigger and complete second bead. Clean and inspect each bead. Continue building pad until it is to size as specified by instructor. — — — —

11. Ask instructor check to finished pad. — — — —

12. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I10, I11 and I12.

# MAKE FILLET WELD IN VARIOUS POSITIONS USING CORED WIRE

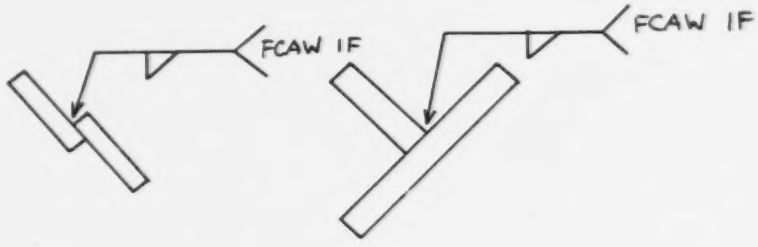
Equipment:

FCAW machine with accessories
Personal safety clothing and equipment
Wire to specifications
Mild steel, as selected by instructor
Wire-cutting pliers
Bench vise
Hammer
Chipping hammer and wire brush

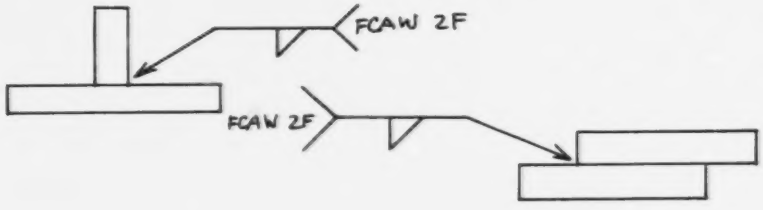
Specifications:

Joint design and weld symbols

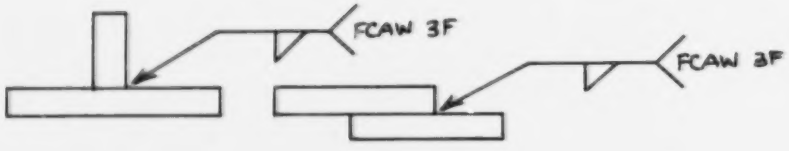
Flat



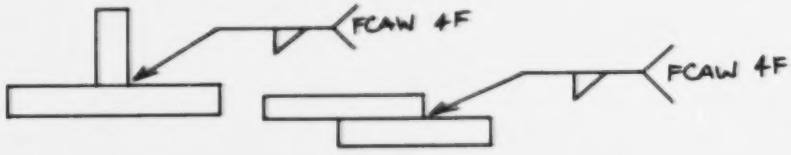

Horizontal




Vertical



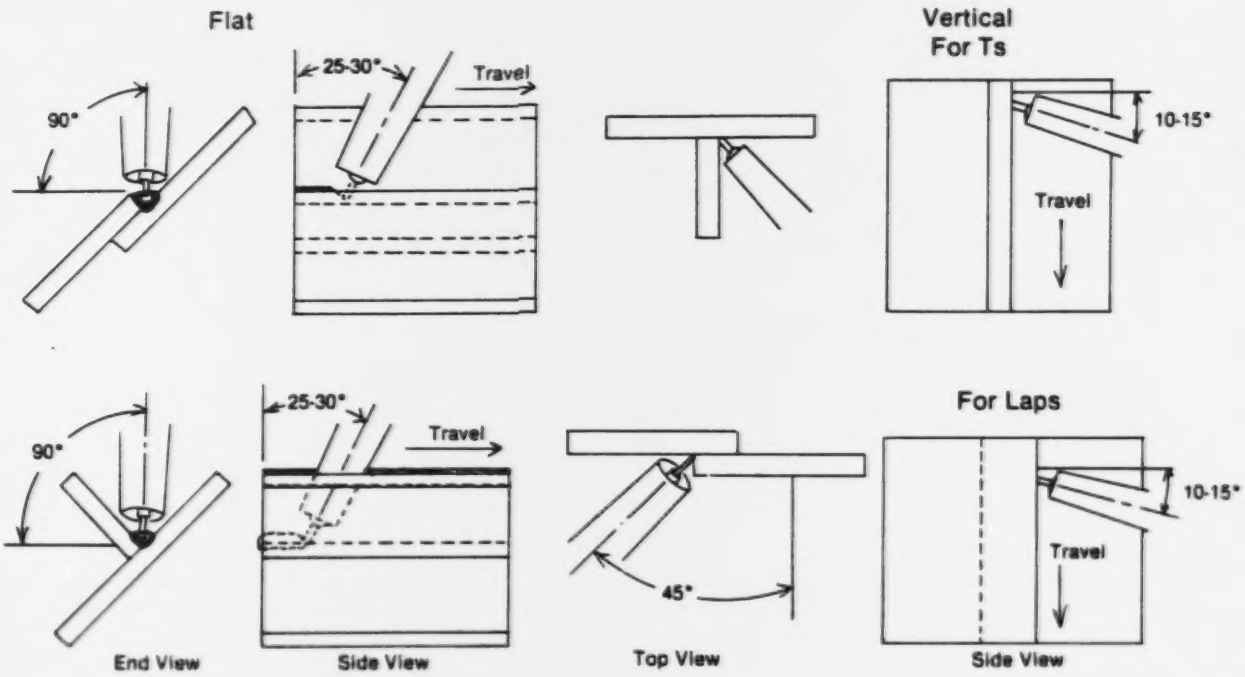

Overhead

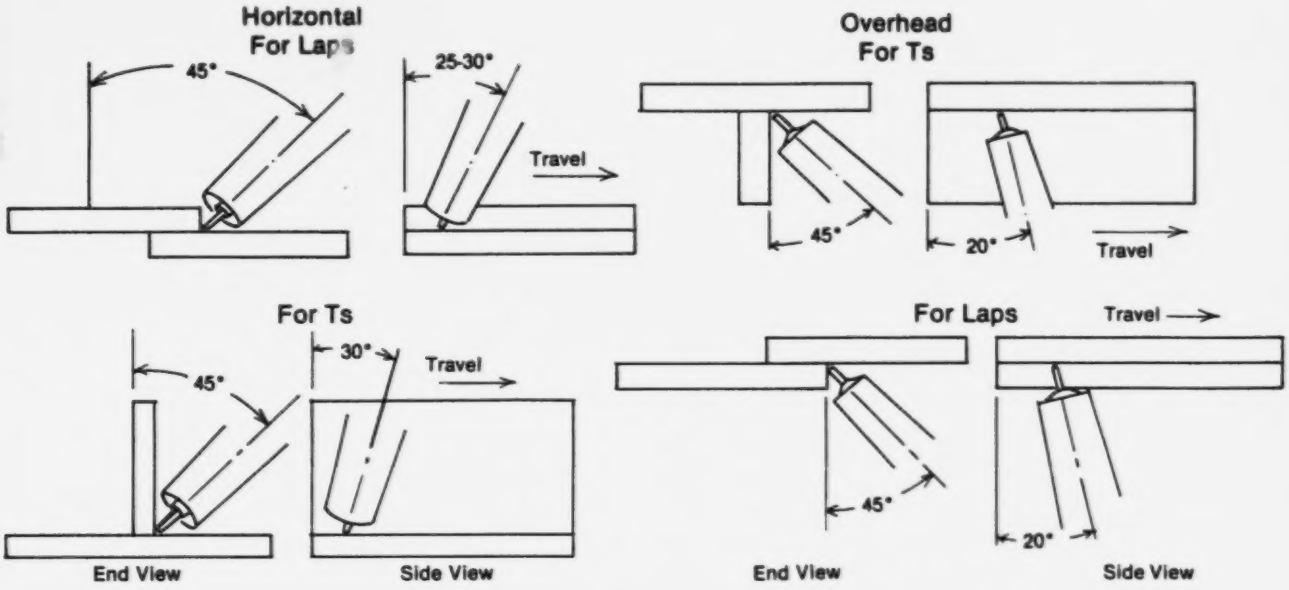



GMAW 157

Wire and wire size: per instructor
Amp/ipm: to recommended setting
Electrical: per electrode selection
ESO: per electrode selection
Positions: 1F 2F 3F 4F
Direction of welding: Vertical down
Technique: pull
Cleaning: chipping hammer and wire brush
Inspection: visual
Testing: break

| Procedure: | Evaluation 3 2 1 N |
|---|---|
| 1. Set up wire feeder and GMAW equipment for FCAW as previously outlined. | — — — — |
| 2. Adjust controls for plate thickness and wire diameter. Make a test bead on scrap metal and make required adjustments. | — — — — |
| 3. Position plates on work table and tack both ends of joint. Position plates in correct welding position. Place gun at correct angle to joint and check ESO. | — — — — |






4. Squeeze gun trigger and use pull technique to weld the joint. Be sure to position yourself so you can see to maintain correct gun angle and ESO. — — — —

5. Crater and fill to end weld; put gun in a safe place. — — — —

6. Clean joint with chipping hammer and wire brush. Inspect joint visually. — — — —

7. Ask instructor to check your work. — — — —

8. Take plates to vise and conduct a break test. Inspect break for good penetration and fusion or defects. — — — —

9. Take plates back to the work table. Retack both ends and weld other side of joint. — — — —

10. Clean and visually inspect joint. — — — —

11. Ask instructor to check your work. — — — —

12. Take plates back to vise and conduct another break test. Inspect break for good penetration and fusion or defects. — — — —

13. Ask instructor to check your work. — — — —

14. Shut down equipment. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competencies I14, I17, I20 and I21.

## MODULE: GAS METAL ARC WELDING

## UNIT VIII: FLUX-CORED ARC WELDING

## UNIT TEST

**Choose the option which best answers the question or completes the statement.**

___ 1. What company introduced a process that turned the electrode wire "inside-out" so that flux materials were inside a tubular wire? When was this process introduced?

a. Lincoln Electric Co., 1958
b. Union Electric Co., 1946
c. General Electric, 1940
d. Southwestern Bell, 1960

___ 2. Why were early experiments coiling and feeding covered electrodes from a reel unsuccessful?

a. Flux cracked too easily
b. Reels were not technologically advanced
c. Wire housing separated
d. Liners were not heavy duty
e. None of the above

___ 3. The developer called the new process _____ , and the new self-shielding electrode wire permitted _____ .

a. Innershield, use of higher amperages and lower deposition
b. Dual shield, use of higher amperages and lower deposition
c. Dual shield, use of higher amperages and provided greater
d. Innershield, use of higher amperages and provided greater deposition

___ 4. Which is <u>not</u> an advantage of FCAW?

a. Eliminates the need for flow meters, shielding gases and piping components that other processes require
b. When not used with a shielding gas, helps eliminate the need for wind shielding and permits fans and ventilators to be used
c. Gives greater deposition rates while increasing welding costs
d. Can reach into places inaccessible by other welding processes

___ 5. Which is <u>not</u> true of FCAW?

a. Provides a one-process operation in both shop and field
b. Intensifies operator training, equipment selection and maintenance
c. Creates smoke in the work area
d. Clean-up required after welding

___ 6. Benefits from learning FCAW include all but which of the following?

a. Introduces student to all-purpose welding
b. Introduces student to high-deposition welding and provides practice with manipulative skills
c. Provides student with basic skills needed for production-type welding
d. Gives student skills in a welding process that is relatively new and highly accepted by industry

**Match the terms on the right with definitions.**

___ 7. Arc welding process where a tubular, flux-filled consumable electrode is fed at a controlled rate into a weld joint

___ 8. Flux-cored wire electrode that protects the weld zone from contaminants with fluxing elements released from the wire's inner core

___ 9. Flux-cored wire electrode used in the presence of a shielding gas to provide double protection and improved mechanical properties

___ 10. FCAW process where welding is controlled as an operator squeezes or releases a gun trigger

___ 11. FCAW process where welding is controlled by mechanical devices programmed for specific applications

___ 12. Length of the electrode from the workpiece to the contact tip within the nozzle

___ 13. Length of electrode that can actually be seen between the workpiece and the nozzle's end

___ 14. Flux-cored wire feeder in which drive roll and control unit are detached from reel housing

___ 15. Flux-cored wire feeder which is attached to the wire reel housing and mounted on a dolly

a. Automatic
b. Dual-shielded
c. Electrical stickout (ESO)
d. FCAW
e. Integrated
ab. Remote
ac. Semi-automatic
ad. Self-shielded
ae. Visible stickout (VSO)

**For the next three questions concerning classifications for FCAW electrode wires, use the sample E70T-4.**

___ 16. What does the "E" mean?

a. Electric
b. Effective
c. Electrode
d. Elongated

___ 17. What does the "0" mean?

a. Electrode may be used in flat or horizontal positions.
b. Electrode may be used in flat or vertical positions.
c. Electrode may be used in vertical or horizontal positions.
d. Electrode may be used in overhead position.
e. None of the above

___ 18. Which is <u>not</u> a guideline for using drive rolls and guide tubes?

a. Drive rolls and guide tubes should be cleaned after each roll of wire electrode is used.
b. Remove accumulated dirt and shavings with a wire brush.
c. Some worn drive rolls can be reversed, but when badly worn should be replaced.
d. When drive rolls slip while wire is being fed into the cable, it indicates the end of the wire has not been properly prepared or that shavings have probably built up in the cable.
e. Drive rolls and guide tubes for wire feeders will usually handle several different sizes of wire.

**Arrange in first to last order the steps for starting an arc with the semiautomatic process.**

___ 19. 1st
___ 20. 2nd
___ 21. 3rd
___ 22. 4th
___ 23. 5th
___ 24. 6th

a. Cut the end of the wire.
b. Position the tip of the electrode just off or just barely touching the base metal.
c. Even when a long stickout is desired, start with about 1/2" visible stickout. Establish the arc as outlined, then increase stickout to desired length.
d. Inch the electrode out beyond the nozzle to just short of the visible stickout recommended for the electrode size and guide tip.
e. Allow arc to establish itself fully, then slowly pull back gun until recommended stickout is established.
b. Squeeze the trigger to start the arc, but don't push electrode into the joint as it starts to burn away.

**Choose the option which best answers the question or completes the statement.**

___ 25. When all other variables are held constant, current variations have which effect?

a. Increasing current increases melt-off and deposition rate.
b. Too little current produces a convex bead that looks bad and wastes metal.
c. High current results in reduced penetration.
d. None of the above

___ 26. When all other variables are held constant, travel speed variations have which effect?

a. Excessive travel speed makes the bead concave with uneven edges.
b. Too slow a travel speed produces slag inclusions and a rough, uneven bead.
c. Neither of the above
d. a and b

___ 27. When all other variables are held constant, electrical stickout variations have which effect?

a. Increased stickout decreases current, and decreased stickout increases current.
b. Increased stickout lowers voltage across the arc.
c. Short stickout gives greater penetration than long stickout.
d. All of the above

___ 28. Which statement is not true of FCAW preparations?

a. Clean the joint of scale, rust, pain, oil, grease and moisture.
b. Use the same location for the ground clamp to obtain the best weld quality.
c. When making tack welds, use the same electrode recommended for the application.
d. Clamp the work cable to the workpiece so that there is good metal-to-metal contact.
e. Never use undersized or badly worn cables.

____ 29. General guidelines for semi-automatic FCAW include _____ .

a. Generally using the highest voltage possible without causing porosity
b. Always increasing arc voltage when current is increased
c. Remembering that travel speed is almost always faster with self-shielded, flux-cored electrodes than with stick electrodes
d. All of the above

____ 30. Safety requirements for FCAW do not include which of the following?

a. Personal safety clothing and equipment should be used when working with FCAW equipment.
b. Procedures for safely operating machines and electrical components should be followed at all times.
c. Working with flux-cored wires requires no special ventilation.
d. Sparks generated by the FCAW process can be excessive and erratic, requiring that the entire welding area be screened from nearby workers or others.

31. List three pieces of equipment required for semiautomatic self-shielded FCAW.

a.

b.

c.

32. List two types of FCAW guns for automatic operation.

a.
b.

## ANSWERS TO UNIT TEST

1. a
2. a
3. d
4. c
5. b
6. a
7. d
8. ad
9. b
10. ac
11. a
12. c
13. ae
14. ab
15. e
16. c
17. a
18. e
19. d
20. a
21. b
22. ab
23. e
24. c
25. a
26. d
27. d
28. b
29. d
30. c

31. Any three of the following:
A constant voltage DC power with a minimum amperage range of 200-400 amps
Electrode input cable
Reel of continuous electrode wire
Electrode feed unit
Work cable and ground
Gun and cable assembly

32. Air cooled, water cooled